

for Lange: note p 3-2

Anito analysis p 420-423
to demonstrate lack of need
for more storage - Use both
reserves to calculate

EAST BAY HILLS FIRESTORM

RESPONSE ASSESSMENT

PHASE II FINAL REPORT

flows as in LA
- possibility of
changing operating
band from 70-8000
to 80-1000

also

p 3-5

3-7

3-8

3-9

3-11

, also p 3-10
of phase I

4-24 emergency
generators

Prepared For The

EAST BAY MUNICIPAL UTILITY DISTRICT

By:

p 5-5 table

p 5-6 for mult front
upgrade that would
be immediately
valuable

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UNIVERSITY OF CALIFORNIA

5-3 "existing" 1500 gpm
standard

5-1, 5-4 in confused

re what's meant

by high head areas

5-4 more than 1500 from one hydrant not useful



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EXECUTIVE SUMMARY

CONTEXT OF THIS ASSESSMENT

This report is Phase II of an assessment arising from the October 1991 firestorm in the East Bay Hills. Phase I of this assessment addressed two questions: 1) How well prepared was the District to respond to the firestorm emergency, and 2) How well did the District respond to the emergency. These questions were evaluated in the Phase I Final Report (July, 1992) and Board Presentation (August, 1992).

The Phase I assessment identified three major limitations of the water distribution system in the October 1991 East Bay Hills firestorm: 1) low flow hydrants, 2) limited fire flow durations (empty reservoirs), and 3) limited multiple front fire suppression capability within single pressure zones.

PRIMARY OBJECTIVES OF THE PHASE II ASSESSMENT

There are two primary objectives of this Phase II assessment:

1. Analyze the District's water distribution system design criteria, operational policies, and practices, and make recommendations about possible changes to enhance the District's capability to perform effectively in future emergencies, and
2. Recommend changes in the District's Water and Wastewater emergency operations plans, emergency equipment, emergency operations team (EOT), emergency operations center (EOC), emergency response training and emergency response exercises to enhance the District's preparedness for future emergencies.

The focus of this report is on Objective 1. Objective 2 of this assessment is addressed separately in an Emergency Operations Plan for the District.

OVERVIEW OF CONTENTS

A detailed study, including hydraulic modeling, has been completed for nine pressure zones within the 1991 Firestorm area. These results have been extrapolated to similar high hazard residential hill areas throughout the District. The general conclusions about the types of distribution system upgrades which would significantly improve fire emergency performance are applicable District-wide.

Chapter 1 provides an overview of this assessment project. Chapter 2 reviews the major hazards facing the District. Chapter 3 reviews District policies bearing on

emergency capabilities. Chapter 4 provides a detailed analysis of the distribution system's current fire flow performance capability in nine pressure zones affected by the October 1991 firestorm and it also summarizes pipe replacements which would suffice to upgrade fire flow rates to proposed standards. Chapter 5 reviews a range of upgrade alternatives and includes detailed summaries of upgrade alternatives in each of the nine pressure zones; cost estimates both for the nine pressure zones and District-wide for the entire high hazard residential hill areas are presented. Chapter 6 presents VSP's recommendations and focuses on Board policy decisions and action items.

MAJOR HAZARDS

- The focus of this assessment is on the water distribution system. The water transmission system is subject to major hazards, including dam failures, aqueduct failures, treatment plant failures, water contamination and droughts, which must also be evaluated when considering system upgrades.
- The water distribution system is subject to several major hazards, including fires, earthquakes, power outages, ground failures (landslides), freezes, floods, and contamination of water supply.



- For the water distribution system, the predominant hazards are earthquake and fire, because these hazards have the greatest potential impacts on the District and the District's customers.



- The primary focus of this assessment is on improving the system's performance in fire emergencies. Improving performance in earthquake emergencies is the subject of the District's Seismic Evaluation Program.

- Three categories of fire hazards are considered:

- Normal Structure Fires

Impact: thousands of single structure fires per year

- Wildland/Urban Intermix Fires

Impact: 14 major fires in the East Bay Hills since 1920
5 fires of 1,000 acres or more
average burn area about 100 acres per year

- Fire Following Earthquake

Impact: uncertain, potentially major.

- Reducing the threat of major fires within the District requires a combination of mitigation measures (vegetation control, building codes, and emergency planning) and response enhancements (fire department resources and water resources). Reducing the fire threat requires complementary actions by fire agencies, local governments, residents, and the District.

POLICY REVIEW

- As defined by the Mission Statement, the District's primary mission is "To manage the natural resources with which the District is entrusted, to provide reliable, high quality water and wastewater services for the people of the East Bay and to preserve and protect the environment for future generations."
- Within the Mission Statement, the sixth goal and priority is to "Improve emergency preparedness through effective disaster planning." This goal is amplified by two major District objectives:

A) Assure safety of District facilities and operations, and

B) Assure maintenance of critical District functions in any disaster.

- What are the District's critical functions in a disaster?

Provide potable water? Providing potable water is the primary goal and priority outlined in the Mission Statement.

Provide water for fire suppression? The District's role in providing water for fire suppression is not clearly defined in existing policy statements.

- Providing water for fire suppression is an important function of the District:

A. District water is used for fire suppression thousands of times per year.

B. The District has over 24,000 fire hydrants.

C. The District maintains fire fighting reserves in its storage reservoirs.

- D. Newer portions of the District's water distribution system were explicitly designed to meet fire flow requirements.
- E. Water Main Planning Criteria explicitly include fire flow criteria for both new and existing development.
- Under current District practice, repair and replacement decisions are based on normal operations and maintenance needs. Upgrades to the existing water distribution system specifically to improve fire or other emergency response capability are not currently done by the District.
- There are several key policy questions:
 - A) Should portions of the existing water distribution system be upgraded to improve fire and other emergency response capabilities?
 - B) If so:
 - To what design level?
 - Who sets the design level?
 - What design level is needed in high hazard areas?
 - How should the design level be accomplished?
 - Who pays?
- Fire flow design requirements for new construction of water distribution systems throughout California are based on the Uniform Fire Code (UFC) standards, as implemented by local fire agencies.
- UFC standards are intended to provide fire flows necessary to contain single structure fires. These standards were not intended for fires like the October 1991 event. Therefore, meeting current UFC standards does not ensure that a water distribution system can provide fire flows adequate for fire suppression efforts in a major wildland/urban intermix fire, or for major fires following an earthquake.

CURRENT WATER DISTRIBUTION SYSTEM PERFORMANCE IN THE FIRESTORM AREA

- The water distribution system in the District's residential hill areas generally has a lower fire emergency performance capability than does the system in other portions of the District. This situation arises because the hill areas are pumped pressure zones, rather than gravity feed zones. Also,

* the generally lower density of development in higher-elevation areas results in limited water storage, smaller pipe sizes, and less cross-linking of mains than in lower-elevation, higher-density areas. Furthermore, in the hill areas, as elsewhere in the District, portions of the system were built to old standards which differ from current standards.

- Hydraulic modeling of nine pressure zones in the 1991 firestorm area indicates that there are 59 hydrants which do not meet the fire flow standard recently proposed by the Oakland Fire Department of 1,500 gallons per minute (gpm) east of Highway 13 and 1,000 gpm west of Highway 13 for new construction. These hydrants constitute about 22 percent of the total of 267 hydrants in these zones.
- Pressure zones which substantially meet the recently proposed fire flow standard of 1,500 gpm still ran out of water during the 1991 firestorm because water storage was insufficient to provide the fire flow durations required during this event.

POSSIBLE DISTRIBUTION SYSTEM UPGRADES

- There are three main types of possible upgrades which would improve the water distribution system's fire emergency performance capability:
 - 1) Upgrade hydrant flow rates,
 - 2) Increase fire flow durations,
 - 3) Enhance multiple front fire suppression capability.
- What would be the impacts of such system improvements?

Better fire emergency performance capability?	YES
Reduced losses in future fires?	YES
Complete elimination of fire losses?	NO
- For each of these types of possible system improvements, there are a range of alternatives ranging from no change in the current system to substantial augmentations of present performance levels, with corresponding differences in benefits and costs. For each type of possible system upgrade, a range of alternatives has been considered.

- Suggested priorities for distribution system upgrades:

1) Upgrade hydrant flow rates: improves system performance for all types of fires.

2) Increase fire flow durations: increasing the total water available substantially improves performance for major wildland/urban intermix fires and fire following earthquake.

3) Enhance multiple front capability (requires increased fire flow durations): highly desirable for major wildland/urban intermix fires and fire following earthquakes, but less critical than increasing total water available for fire suppression.

- In considering the range of possible upgrade alternatives, there may be trade-offs between mitigation activity and necessary system performance upgrades.
- The preferred distribution system upgrade alternatives for single family residential areas are:

Can we even
do this?

1) upgrade hydrants to the proposed standards of 1,500 gpm in high hazard areas and 1,000 gpm elsewhere,

2) increase fire flow durations by increasing fire emergency water storage to 720,000 gallons per pressure zone in high hazard areas,

3) enhance multiple front fire suppression capability in high hazard areas.

ESTIMATED COSTS

- The estimated costs for the three preferred distribution system upgrade alternatives are summarized in the following table. The system-wide cost estimates are based on a preliminary determination of the high hazard area and on rough extrapolations from the eleven pressure zones studied in more detail. The system-wide estimates are subject to revision upon more detailed study.

1500 gpm E of B
1000 gpm W of B

ESTIMATED COSTS: UPGRADES FOR HIGH HAZARD AREAS		
UPGRADE	COST ESTIMATES (MILLIONS OF DOLLARS)	
	ENTIRE HIGH-HAZARD AREA	11 FIRE-AREA PRESSURE ZONES
INCREASE HYDRANT FLOWS RATES TO PROPOSED STANDARDS	\$40 - \$60	\$6
INCREASE FIRE FLOW DURATIONS (720,000 gallons storage)	\$45 - \$65	\$5 - \$6
ENHANCE MULTIPLE FRONT CAPABILITY	\$20 - \$30	\$2
TOTAL COSTS	\$105 - \$145	\$13 - \$14

FINANCING ALTERNATIVES

- The principal financing alternatives are to allocate distribution system upgrade costs District-wide or locally within the areas which benefit directly from the upgrades.

- District wide {
- We suggest that the cost of upgrades attributable to expected normal maintenance and repair and the costs to upgrade hydrants to the as-built fire flows be allocated District-wide. This recommendation would continue current District practices.

- could be either {
- The cost of upgrades to current performance levels, for portions of the system where as-built standards are significantly below current standards, could be allocated either District-wide or locally. Current District practice is to make such upgrades only when replacements are dictated by operations or maintenance reasons, but to allocate costs District-wide. ~~to~~ to 1000 gpm standard

- local {
- The costs of any upgrades beyond current performance levels (for example, fire flow rates above 1,000 gpm, increased fire flow durations or multiple front capability) directly reflect local high hazard conditions and the benefits of such upgrades are local. Therefore, we suggest that the costs of such upgrades be allocated locally to those who benefit directly.

- Formation of special assessment districts for upgrades beyond current performance levels could involve residents directly in making choices about the level of emergency performance

they desire from the water system. If residents approve special assessments, then upgrades beyond current performance levels could be implemented.

RECOMMENDATIONS

- ✓ • The District should take a leadership role among public agencies in helping to encourage fire hazard mitigation actions by public and private agencies and residents throughout its service area.
- ✓ • The District should work proactively with fire agencies within its entire service area to encourage these agencies to delineate high hazard areas and to develop fire flow standards appropriate for these areas.
- ✓ • In evaluating alternative system upgrades, fire-based upgrades should not be considered in isolation from other demands on District resources. A coherent and coordinated system-wide repair/upgrade plan should balance and prioritize system improvements considering: normal operations and maintenance, water quality, environmental impacts, fire emergency performance, post-earthquake emergency performance, and distribution system upgrades versus transmission system upgrades.
- There are a wide range of possible distribution system upgrade alternatives to improve fire emergency performance. In the order of importance, recommended upgrade priorities are:
 - 1) increase hydrant flow rates for hydrants which are substantially below current standards,
 - 2) increase water storage in pumped pressure zones, especially zones with smaller reservoirs, and
 - 3) enhance the distribution system's ability to support concurrent fire suppression efforts at multiple locations within a single pressure zone.

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1.0 INTRODUCTION

1.1 SCOPE OF THIS ASSESSMENT

The Phase I Final Report¹ presented retrospective analyses of how well prepared the District was to respond to the October 1991 East Bay Hills Firestorm emergency and how well the District responded to the emergency. The Phase II analyses in the present report are prospective in that they provide recommendations about possible changes to enhance the District's capability to perform effectively in future emergencies and recommendations to enhance the District's future emergency planning.

There are two primary objectives of the Phase II assessment:

- 1. Analyze the District's water distribution system design criteria, operational policies, and practices, and make recommendations about possible changes to enhance the District's capability to perform effectively in future emergencies, and**
- 2. Recommend changes in the District's Water and Wastewater emergency operations plans, emergency equipment, emergency operations team (EOT), emergency operations center (EOC), emergency response training and emergency response exercises to enhance the District's preparedness for future emergencies.**

This Phase II report addresses the first primary objective and contains specific recommendations for a range of possible improvements in the District's water distribution system and in its emergency management programs. The second primary objective, to recommend changes in the District's emergency operations plans is addressed in a separate companion report.

1.2 OVERVIEW OF THE REPORT

A detailed study, including hydraulic modeling, has been completed for nine pressure zones within the 1991 Firestorm area. These results have been extrapolated to similar high hazard residential hill areas throughout the District. The general conclusions about the types of distribution system upgrades which would significantly improve fire emergency performance are applicable District-wide.

Chapter 2 provides a review of policy issues pertaining to the District's emergency response capability. This chapter includes reviews of the Board's Mission statement, key Board policy questions, fire flow standards, the practices of the District and other water agencies for providing fire flows, and other related policies.

Chapter 3 provides an assessment of the major hazards which potentially could

impact the District. The potential impacts of these hazards are evaluated using the Office of Emergency Services three-level classification system for emergencies. The two hazards, wildland/urban intermix fires and earthquakes, which have the greatest impact on the District are assessed more quantitatively, including probabilities of occurrence.

Chapter 4 provides a detailed analysis of the current fire-flow performance capability for the pressure zones within the fire area. Hydraulic analyses were conducted to evaluate the fire-flow capability of each hydrant within this area. This chapter also contains specific upgrades (primarily pipe replacements) which are necessary to bring the low flow hydrants up to current fire flow standards. The current system's performance capability for other hazards is also reviewed.

Chapter 5 reviews a range of upgrade alternatives, including upgrading low flow hydrants, increasing fire flow durations, and enhancing multiple front fire suppression capability. For the nine zones studied in detail, upgrade alternatives are assessed and specific upgrades are recommended. Cost estimates are provided, for the nine pressure zones and District-wide for the entire high hazard residential hill areas. This Chapter also considers design criteria, operating procedures, repair and replacement practices, and possible future funding alternatives.

Chapter 6 provides a summary of a recommendations and with a focus on Board policy/action items.

Chapter 1 Endnote:

1. East Bay Hills Firestorm Response Assessment, Phase I Final Report; VSP Associates, Inc.; G&E Engineering Systems, Inc.; and Barbara Foster Associates; July 15, 1992.

2.0 HAZARDS ASSESSMENT

2.1 OVERVIEW OF HAZARDS

The District's water and waste water system consists of a complex network of infrastructure, including reservoirs, transmission aqueducts, terminal reservoirs, treatment plants, storage reservoirs, pumping plants, distribution mains, regulators, valves, other ancillary equipment and individual customer services, as well as numerous administrative, storage, maintenance and communications facilities. All components of the District's infrastructure and operations are subject to potential disruption, damage, or destruction from natural or man-made hazards.

The affect of natural or man-made hazards on the District could vary from very minor, local problems to major system-wide damage and disruption of critical functions. Hazards can impact the District's normal operations and ability to provide established essential types of service either by interrupting water supply (e.g, pipe breaks), or by imposing extreme emergency water demands (e.g., a major firestorm), or both simultaneously (e.g., a major earthquake with numerous pipe breaks and numerous post-earthquake fires).

The Emergency Level Classification used by the California Office of Emergency Services provides a useful means of distinguishing the impacts caused by various levels of emergencies. "Ordinary emergencies," which are purely local in impact, are not included in this classification because the response and recovery can be readily accomplished by available crews and resources. The three level emergency scale summarized below is for events which would require a large fraction of the District's total response capability or would exceed the District's total response capability:

Level I: These events cause interruptions of service which are within the capability of the District to respond, but where the District's ability to respond may be dangerously extended. These moderate events are reportable to the State OES upon request. Examples of Level I emergencies include a reportable large hazmat spill or a small/moderate earthquake that affects the service area.

Level II: These moderate to severe events require the full resources of the District or the coordination of several nearby utilities/agencies. The State OES Utility Operations Center (UOC) is activated on either a limited or full basis. Examples of Level II emergencies include a large fire or a moderate/severe earthquake that affect the service area.

Level III: These emergencies are major incidents that require deployment of response resources from throughout the state and possibly from other states as well. A Level III emergency is likely to be a major earthquake which would severely impact the District's infrastructure. The OES Utilities Emergency Plan would be fully activated.

The District's water transmission system is subject to major hazards, including dam failures, aqueduct failures, treatment plant failures, contamination of water supplies, and droughts. Major events of these types would be Level II or Level III emergencies and thus must be considered in emergency planning and be evaluated when considering system upgrades. However, the focus of this assessment is on the water distribution system.

Hazard assessments for the District's service areas have been conducted as part of the general planning process for Alameda and Contra Costa Counties as well as for the individual cities within the service areas (particularly Berkeley and Oakland). These general plans are an excellent source of more detailed information on the hazards which are briefly discussed below.¹ Among the hazards faced by the District's distribution system are:

1. fire
2. earthquakes
3. power outages
4. ground failure (landslides)
5. dam failure
6. freeze
7. floods
8. contamination of water supplies
9. hazardous material incidents.

The potential impact of these hazards may be evaluated on the Emergency Level Classification of the California Office of Emergency Services. The two hazards with the greatest potential impact on the District (i.e., Level II or Level III Emergencies) are fire (especially large wildland/urban intermix fires) and earthquake. The other hazards are likely to produce "local emergencies" or Level I emergencies. Furthermore, the emergency response capability (hardware and operations) necessary to respond to Level II or Level III fire or earthquake emergency will provide good emergency response capability for the impacts of the lesser hazards.

Therefore, recommendations to enhance the District's emergency preparedness and response capability focus primarily on the fire and earthquake hazards. The fire and earthquake hazards are assessed in the following two sections of this chapter. These sections include summaries of the probable impacts of major fires and major earthquakes on the District and probabilistic risk assessments of the likelihood of these emergencies. The impacts of the lesser hazards are reviewed following the fire and earthquake sections. The District's Emergency Operations Plan² provides a framework to coordinate response and recovery for emergencies generated by all of the hazards facing the District.

The primary focus of this assessment is on improving the system's performance in fire emergencies. Improving performance in earthquake emergencies is the subject of the District's Seismic Evaluation Program.

2.2 FIRE HAZARDS

Providing water for fire suppression efforts is an important function of the District's water system. Fire hazards in the District's residential service areas may be categorized into three major types of hazards: 1) "normal" structure fires, 2) wildland/ urban intermix fires, and 3) fires following earthquake. Each of these types of fire hazards places different water demands on the distribution system and thus must be considered separately.

Fires may locally damage District facilities or disrupt electric power to portions of the service area. However, the primary impact of fires on the District is to increase the demands for fire suppression water. If the demand for fire suppression water is unusually large, as in a major wildland/urban intermix fire, then the increased water demands may initiate operational responses from the District. For example, emergency pumps, portable generators, and other emergency equipment may have to be deployed, water supplies may be redirected via regulators or zone gates, and the District's Emergency Operations Center may be activated.

2.2.1 "Normal" Structure Fires

"Normal" structure fires, which typically involve only a single structure and occasionally spread to involve nearby structures, occur frequently within the District's service area. Within most portions of the service area, the District's water distribution system provides fire flows that are more than adequate to suppress "normal" structure fires. In high-density areas of the system, water main sizes and reservoirs are large and there are many interconnections between distribution mains. Therefore, in such areas, high fire flows are available from many hydrants to fight "normal" structure fires or large structure fires involving several structures. In other words, water supply limitations are not a factor in suppression of structure fires in such areas.

In lower density, residential portions of the service areas, distribution mains are smaller and there are fewer interconnections of mains. Therefore, available fire flows are less than in higher density areas. In newer portions of the service area, the distribution system has been designed and built to current fire-flow standards. In such areas, hydrant flows of 1,000 or 1,500 gpm are typically available. Such fire flows conform to current UFC fire-flow requirements and are sufficient to suppress structure fires in these areas.

As discussed in the Phase I report,³ older portions of the District's distribution system were built to different standards than were more recent portions. In some of these older portions of the system, small pipe diameters limit fire flows to values lower than current UFC fire-flow standards for new construction. Chapter 4 of this report presents the results of hydraulic modeling of the distribution system in the October 1991 firestorm area, including assessments of the fire-flow capability of all hydrants in the area modeled. Chapter 5 presents alternative upgrade strategies for the distribution system, all of which would substantially improve the fire-flow capability in these older portions of the system.

2.2.2 Wildland/Urban Intermix Fires

Significant portions of the District's service area are subject to wildland/urban intermix fires. Wildland fires are those which burn vegetative fuel loads - grass, brush, and trees. Areas of the District which contain high vegetative fuel loads, primarily the hill areas, are subject to major fires involving both structures and vegetative fuels. In many of the hill areas, the fire hazard may be very high during the dry season because of a combination of factors, including: high temperatures, low humidity, high winds, high vegetative fuel loads (in some cases augmented by freeze-caused dead debris), steep topography, and narrow winding streets which restrict access and egress.

The October 1991 East Bay Hills firestorm, which destroyed over 3,000 structures, is the most devastating wildland/urban intermix fire which has occurred in the United States. Within the District, other major wildland/urban intermix fires occurred in Berkeley in 1923 (about 500 structures burned) and in Oakland in 1970 (37 structures burned). In addition to the Oakland-Berkeley hill area, several other portions of the District are also high-risk areas for wildland/urban intermix fires. These areas include the El Cerrito, Kensington, and Richmond hills north of Oakland-Berkeley, as well as the hill areas extending south through San Leandro and Castro Valley. Areas on the eastern slope of the hills, including Orinda and Lafayette are also high-risk areas for wildland/urban intermix fires. Other portions of the District, including the neighborhoods immediately west of Highway 13 are at moderate-to-high risk of wildland/urban intermix fires.

Wildland/urban intermix fires differ substantially from "normal" structure fires in terms of the water demands required for suppression. First, because of the potential magnitude of wildland/urban intermix fires, the total fire flows required may be much larger than required for suppression of "normal" structure fires. Second, wildland/urban intermix fires may involve a large geographic area, and thus involve many pressure zones simultaneously. Third, wildland/urban intermix fires are likely to occur in portions of the District where the development density is relatively low and thus the capacity of the distribution system to supply fire flows is more limited than in higher density development areas. These three attributes of wildland/urban intermix fires combine so that such fires may impose heavy demands on the system's capability.

Designing/planning for wildland/urban intermix fires is complicated by the relatively infrequent occurrence of major fires. Within the East Bay Hills, for example, fourteen wildland/urban intermix fires, of varying severity, have occurred within the last 70 years. During this same time period, many thousands of "normal" structure fires have occurred and thus it is much easier to estimate both the frequency and the magnitude of expected structure fires than it is to estimate the frequency and magnitude of major wildland/urban intermix fires. The risk of major wildland/urban intermix fires has gradually increased over the decades as development has extended into previously undeveloped hill areas. Furthermore, the increasing introduction of largely non-native vegetation has added to the fuel load and thus increased the fire threat.

A recent report by the East Bay Regional Park District⁴ reviewed historical experience with wildland/urban intermix fires in the Oakland/Berkeley hills. Between 1923 and 1991, this report indicates 14 intermix fires. These fires burned a total of about 8500

acres, with five fires burning 1,000 to 1,800 acres and nine fires burning less than 1,000 acres (between 2 and 700 acres). A total of about 3600 houses were burned, with nearly all of these being in the 1923 and 1991 fires. Housing density in the hills has greatly increased since the 1920s; therefore, the house losses in earlier fires are probably not indicative of likely future losses. In most of the high-hazard hill areas, housing density is close to build-out and the extent of vegetative fuel load is not likely to increase substantially. Therefore, the present fire situation is likely to continue into the future.

These data indicate that wildland/urban intermix fires have occurred, on average, once every five years in this area. Over this time interval, an average of 125 acres per year have been burned. These statistics on the frequency of fires and acres burned per year are fairly reliable because no single event dominates the statistics. Projecting these estimates into the future is subject to uncertainty. An average of one fire every five years is probably approximately correct. However, increasing development over the decades, with corresponding increases in the extent of the water system and decreases in the extent of high-vegetative fuel wildlands, may reduce the probability of fire ignitions spreading into large area fires. With a significant uncertainty, we estimate that an average of approximately 100 acres per year may be expected to burn.

The area considered in the East Bay Regional Parks District report contains approximately two-thirds to three-quarters of the District's entire high hazard residential hill area. Therefore, for the District as a whole, the expected average annual acres burned would be proportionately higher than the figures quoted for the report area.

Despite the difficulty of estimating the expected frequency and intensity of future major wildland/urban intermix fires in the District's high hazard residential hill areas, it is relatively straightforward to estimate the maximum credible impact of such fires on the water distribution system. Fires larger than the October 1991 East Bay Hills firestorm are certainly possible. However, the impact of the October 1991 firestorm on the affected pressure zones was close to the maximum possible: in particular, several pressure zones in the same pumped cascade were fully or nearly fully involved in the fire. In an even larger fire, more pressure zones would be affected, but the impact on individual pressure zones would be similar to that experienced in the October 1991 firestorm. Therefore, we will use the experience of the October 1991 firestorm as the benchmark against which the fire emergency response capability of the water distribution system will be compared. The system upgrades discussed and recommended in Chapters 4 and 5 are those deemed necessary for the system to respond effectively to major wildland/urban intermix fires similar in intensity (but perhaps larger or smaller in area affected) to the October 1991 firestorm.

2.2.3 Fire Following Earthquake

Fire following earthquake could be a major hazard for the District. A major earthquake, particularly on the Hayward fault, is expected to cause major damage to the District's water transmission and distribution systems. Damage could include loss of major transmission aqueducts for extended periods of time, failure of numerous reservoirs, and a large number of distribution system pipe breaks. As a result of numerous pipe

breaks, the water supply (including fire reserves) in reservoirs which survive the earthquake could quickly be lost. Expected power outages and the loss of major transmission facilities may make it difficult to replenish reservoirs quickly. Thus, following a major earthquake, major portions of the District's service area could be essentially without water - either for normal uses or for fire suppression.

The expected extent of fire following a major earthquake is very difficult to estimate. San Francisco (1906) and Tokyo (1923) experienced devastating fires which burned tens of thousands of structures in San Francisco and hundreds of thousands of structures in Tokyo. Current earthquake planning scenarios for Tokyo predict that a recurrence of the 1923 earthquake would again result in the loss by fire of hundreds of thousands of structures in Tokyo.

Estimating the extent of fire following a major earthquake in the District, for example on the Hayward fault, is extremely difficult. Fires due to building failures and gas system pipe breaks are virtually inevitable. Whether such fires spread to major conflagrations which destroy large portions of the affected cities depends on several difficult to predict factors, including availability of water for fire suppression, availability of fire fighting personnel and equipment, and weather conditions. However, given the experience in San Francisco and Tokyo, the District should place a high priority on decreasing the vulnerability of its system to earthquake damage and on emergency planning for effective post-earthquake response and recovery.

2.3 OTHER HAZARDS

Earthquakes

It is widely recognized that the entire San Francisco Bay region, including the entire EBMUD service area faces moderate to high earthquake risk. The severity of the earthquake hazard facing the District's service area has been addressed in numerous publications, including the general plans¹ referenced at the beginning of this chapter and in planning scenarios for major earthquakes on the Hayward⁵ and San Andreas⁶ fault systems. The impact of earthquakes on lifelines, including water systems, has recently been reviewed by a major Applied Technology Council Report.⁷

Earthquake damage can be caused by several interrelated effects, including:

1. Fault displacement and ground rupture,
2. Ground shaking,
3. Ground failure (liquefaction, cracking, subsidence, lateral spreading),
4. Slope failures (landslides, debris flows, mud flows, rocks falls),
5. Other effects (dam failures, levee failures, reservoir failures, aqueduct failures, tsunamis, seiches).

Assessment of the expected performance of the District's water distribution system in earthquakes is part of the District's ongoing Seismic Evaluation Project.⁸ Therefore, the seismic hazards faced by the District are not reviewed in detail here. We note, however, that in major earthquakes the distribution system is expected to suffer significant damage including numerous pipe breaks, pumping plant failures, prolonged loss of grid power, and damage to reservoirs.

Prolonged Power Outages

Prolonged power outages could significantly impact the District's service area. However, most key facilities are equipped with emergency generators and the District has additional portable generators which can be deployed where needed in an emergency. The District has over 40 fixed-location emergency generators and about a dozen portable units. These generators, along with fuel tanks, are widely dispersed throughout the District's service area. For most emergencies, including major fires the District has sufficient generators to provide emergency power where needed, such as a pumping plants. For a prolonged Level III emergency, such as a major earthquake, additional generators would almost certainly be needed. Equipment support/supply agreements should be made ahead of time with vendors and other utilities to supply this equipment as needed. Such agreements should include utilities out of the immediate area, because in a major earthquake the demand for such equipment may exceed the total available locally.

Ground Failure

Ground failure (landslides, mudslides, rock falls, avalanches, debris flows) are a significant hazard in many of the hill areas of the District. However, the potential impacts of landslides on the distribution system are largely local (e.g., pipe breaks) and thus, are generally readily repairable. A major earthquake could induce numerous ground failures with significant impact on the District. Minimizing the impacts of landslides can be affected by avoiding landslide-prone areas or stabilizing slides where possible and by increasing redundancy in the water system. Other potential upgrades to the distribution system have little impact on the system's vulnerability to landslide damage. We note, however, that some possible emergency management decisions, such as obtaining portable above-ground water systems for emergency use, would also be beneficial in quickly restoring temporary service after landslide damage.

Dam Failure

Possible dam failures within the District's infrastructure affect the transmission system and the 23 open-cut reservoirs in the distribution system. For life safety reasons, as well as for ensuring the availability of water supplies, dam safety should continue to be a high priority for the District. Dam safety is particularly significant in combination with the seismic risk faced by the District.

Freeze

An intense freeze, such as that which occurred during the winter of 1990-1991, can have a significant impact on water demand. Because of the prevailing mild temperatures in the service area, common local construction practices do not provide adequate protection against water pipes freezing during unusually cold periods. An intense freeze can substantially increase water demand due to freeze-damaged services and due to customers running water continuously to attempt to avoid freeze-damage. For example, between December 19, 1990 and January 2, 1991 California experienced such severe freezing weather that the Governor declared a state of emergency. During this period, the District responded to nearly 1,200 requests for emergency water shut-offs due to ruptured piping in customers' services. However, freeze damage appears unlikely to significantly affect the District's infrastructure or to result in such extreme water demand that the District's operational and emergency water storage inventories would be unable to meet the demand. Distribution system upgrades for fire and/or earthquake would augment response capability for freeze emergencies as well; therefore, freeze-specific upgrades are not required.

Flooding

Flooding within the District's service area could occur from a number of events including: extreme precipitation, rapid snow melting, levee failure, dam failure, reservoir failure, major aqueduct failure, or seismically induced subsidence. Historically, flooding has not been a major problem within the District and the impacts of flooding are typically relatively localized. Therefore, particularly with respect to possible upgrading of the District's distribution system, the flood hazard does not appear substantial. We note, however, that some District facilities could cause a life-safety flooding hazard if they were to fail (for example, in an earthquake). Such District facilities include dams, seismically-vulnerable reservoirs at some locations with residences within the inundation areas, and portions of the aqueduct system with residences within the inundation areas. Therefore, we recommend that the District place a high priority on ensuring that life-safety enhancements are made for such facilities where necessary.

Contamination of Water Supplies and Hazardous Material Incidents

Contamination of water supplies (due to a hazardous material spill or deliberate action) could significantly impact the District. Likewise, hazardous materials incidents could have substantial local impacts. Planning for such emergencies is included in the Emergency Operations Plan update; a separate report in progress under the second major objective of this project (see Chapter 1). However, contamination or hazardous material incident emergencies do not appear significant with respect to assessing possible distribution system upgrades.

Chapter 2 Endnotes:

1. City of Berkeley Master Plan, Adopted 1977.

City of Berkeley Multi-Hazard Functional Plan for Emergency Operations, 1992.

City of Berkeley Fire Hazard Mitigation Plan; October 20, 1991 East Bay Hills Conflagration. Disaster Declaration under FEMA 919-DR-CA; Feb. 25, 1992.

Environmental Hazards; An Element of the Oakland Comprehensive Plan, Sept. 1974.

City of Oakland Emergency Plan. (undated)

City of Oakland Fire Hazard Mitigation Plan. Disaster Declaration under FEMA 919-DR-CA, April 1992.

Contra Costa County General Plan (Safety Elements), Jan. 1991.

Enclosure 5 (Contra Costa County Hazards) to the Contra Costa County General Plan, June 1991.

Seismic Safety and Safety Elements of the County of Alameda General Plan, August 5, 1982.
2. East Bay Municipal Utility District, Emergency Operations Plan, Draft, December, 1992.
3. East Bay Hills Firestorm Response Assessment, Phase I Final Report; VSP Associates, Inc.; G&E Engineering Systems, Inc.; and Barbara Foster Associates; July 15, 1992.
4. East Bay Regional Park District, untitled draft report and map, undated, circa 1992.
5. Earthquake Planning Scenario for A Magnitude 7.5 Earthquake on the Hayward Fault in the San Francisco Bay Area. Special Publication 78, Calif. Dept. of Conservation, Division of Mines and Geology, 1987.
6. Earthquake Planning Scenario for a Magnitude 8.3 Earthquake on the San Andreas Fault in the San Francisco Bay Area. Special Publication 61, Calif. Dept. of Conservation, Division of Mines and Geology, 1982.
7. Applied Technology Council, ATC 25, Seismic Vulnerability and Impact of Disruption of Lifelines in the Conterminous United States, 1991.
8. East Bay Municipal Utility District, Levels of Service for Post Earthquake Water System Performance, Feb. 19, 1992.

3.0 POLICY REVIEW

3.1 BOARD MISSION STATEMENT

District policies with respect to emergency response capability, emergency preparedness, and all other major issues are ultimately determined by the Board of Directors. The District's Mission Statement and corresponding goals, priorities, and objectives have recently been adopted by the Board.¹ As defined by the Mission Statement, the District's primary mission is:

To manage the natural resources with which the District is entrusted, to provide reliable, high quality water and wastewater services for the people of the East Bay and to preserve and protect the environment for future generations.

In the context of the present assessment, the key part of this statement is "to provide reliable, high quality water and wastewater services." The Mission Statement is accompanied by eight major goals and priorities:¹

1. Provide a reliable and adequate high quality drinking water supply.
2. Exercise leadership on water and wastewater issues.
3. Support and serve the community.
4. Enhance the District's work environment.
5. Protect the District's watersheds.
6. Improve emergency preparedness through effective disaster planning.
7. Assure financial stability.
8. Continue environmentally sound wastewater practices.

District policy with respect to emergency issues is addressed in Goal/Priority 6: Improve emergency preparedness through effective disaster planning. This Goal/Priority is amplified by two major objectives which are contained in the Mission Statement dealing with emergency preparedness:¹

- A. Assure safety of District facilities and operations, and
- B. Assure maintenance of critical District functions in any disaster.

not necessarily so

The objective to "assure maintenance of critical District functions in any disaster" leaves unspecified what are the "critical District functions." Providing potable water is the primary goal and priority outlined in the Mission statement and thus is also the primary District function in any disaster. Providing water for fire suppression is not explicitly stated in the Mission Statement's goals, priorities or objectives. However, providing water for fire suppression is an important function for the District, as evidenced by the observations that:

- A. District water is used for fire suppression thousands of times per year.
- B. The District has over 24,000 fire hydrants.
- C. The District maintains fire fighting reserves in its storage reservoirs.
- D. Newer portions of the District's water distribution system were explicitly designed to meet fire flow requirements.
- E. Water Main Planning Criteria explicitly include fire flow criteria for both new and existing development.

The Mission Statement "to provide reliable, high quality water and wastewater services" and Goal/Priority 6: "improve emergency preparedness through effective disaster planning" set the board policy context of the District's emergency policies. In detail, however, District policies on emergency-related issues are established by Engineering Standard Practices, Regulations Governing Water Service to Customers, other District documents, and operational practices and procedures.

The District's Emergency Operations Plan² outlines emergency response priorities during emergencies. The allocation of resources and coordination of response priorities for the restoration of water service area as follows:

- Firefighting
- Critical facilities, including hospitals
- Utilities, including power, communication, and transportation
- Mass care shelters and schools
- Residences
- Businesses

More detailed response and recovery objectives are outlined in Section 5.8 of the District's Emergency Operations Plan.²

The preceding review of the Board's Mission Statement and related policy

documents reveals a surprising omission: providing water for firefighting is listed as the first service restoration priority in the Emergency Operations Plan, but providing water for fire suppression is not listed as a major priority in the Mission Statement. The first Mission Statement/Goal is to provide a reliable and adequate high quality drinking water. Clearly, this is the central day to day function of the District and the primary priority in a disaster. However, providing water for fire suppression is also an important District function. Therefore, we suggest that the Board augment its Mission Statement to explicitly include water for fire suppression as one of the District's important functions.

3.2 KEY BOARD POLICY QUESTIONS

As discussed in Chapter 1, one of the primary objectives of this assessment is to make recommendations about possible changes to enhance the District's capability to perform effectively in future emergencies, with the primary focus of this report being on fire emergencies. In considering possible distribution system enhancements, a central question is:

What is acceptable performance for the District with respect to emergency response capability?

For fire emergencies, there are several key questions:

1. Do current Uniform Fire Code (UFC) standards provide an acceptable level of performance for high hazard residential hill areas, or do these areas require a higher level of water system performance?
2. Should portions of the existing water distribution system be upgraded to improve fire and other emergency response capabilities?
3. If so, to what level should they be upgraded?
4. How should system improvements be financed?

Under current District practice, repair and replacement decisions are based on normal operations and maintenance needs. Upgrades to the existing water distribution system specifically to improve fire or other emergency response capabilities have generally not been done by the District. Therefore, a policy to explicitly include emergency performance capability in the repair/replacement/upgrade decision-making process would represent a significant policy change for the District.

3.3 FIRE-FLOW STANDARDS

The primary focus of this assessment is on fire. The review of current distribution system performance in the firestorm area (Chapter 4) focuses on fire flows available and on the upgrades necessary to bring low flow hydrants up to current fire flows. The distribution system upgrades considered in Chapter 5 deal primarily with enhancing fire response capability beyond current standards, including increasing fire flow durations and enhancing the system's ability to supply water for fire suppressions concurrently to multiple fronts within a single pressure zone.

There are two principal factors which determine a water distribution system's fire suppression capability: fire flows (water flow rate, pressure and duration) and hydrant spacing. Fire flows depend on the physical characteristics of the water system, including: water storage capacity, pumping plant capacity, pipe flow capacities (pipe diameter and hydraulic condition), and system layout. Fire flows are the best single indicator of a water system's fire suppression capability. Hydrant spacing within the nine pressure zone study area, and generally throughout the District, meet UFC standards and thus hydrant spacing is not an issue in this assessment. No problems were reported with hydrant spacing during the 1991 firestorm.

A water distribution system can supply a specified fire flow by having sufficient storage, by having sufficient pumping capacity, or by a combination of storage and pumping capability. The District generally relies on sufficient water storage to ensure fire-flow availability. This approach is conservative, because fire flows are provided from storage reservoirs by gravity flow, independent of the availability of power or the functioning of pumping plants. There are, however, alternative strategies for providing fire flows, which are discussed in Chapter 5 where possible upgrade alternatives are evaluated.

3.3.1 The California Fire Code

The most recent California Fire Code (Title 24, California Code of Regulations, Part 9 (1992)) became effective on August 14, 1992. As of that date, all occupancies in California, including those in cities or counties which had not previously passed fire codes, were covered by this regulation. The California Fire Code, which is adopted by the California State Fire Marshal's Office, incorporates the 1991 Uniform Fire Code (UFC), along with a number of California-specific amendments, which are primarily administrative. The UFC is adopted by the International Fire Code Institute, which consists of the International Conference of Building Officials, the International Association of Fire Chiefs, and Western Fire Chiefs Association, after a thorough review, comment, and revision period. Cities or counties in California cannot modify the provisions of the UFC adopted by the California Fire Code without specific findings which demonstrate that modifications to the code are reasonably necessary because of local climatic, geological or topographical conditions (§17958.7 California Health and Safety Code).

The California Fire Code includes the fire-flow and hydrant spacing requirements of the UFC, as specified in Appendices III-A and III-B, respectively. These UFC requirements

are included in their entirety in Figures 3-1 and 3-2. Fire flows are measured at a residual water pressure of 20 pounds per square inch (psi).

For residential areas with one- and two-family dwellings, the minimum fire-flow requirement is 1,000 gallons per minute (gpm). Current or proposed fire flows for the District's one- and two-family residential areas range from 1,000 to 1,500 gpm. Under the UFC, fire flows of 1,750 gpm or less are to be met with a minimum of one hydrant. For the present analysis, we assume, conservatively, that fire flows are to be met with a single hydrant. The duration requirement of two-hours for one- and two-family residential areas appears to have been inadvertently omitted from the 1991 UFC; we assume, following fire agencies' practice, that previous UFC duration requirements were intended to be continued. Thus, the fire flow duration requirement for one- and two-family residential areas is two hours.

For areas where dwellings exceed a fire area of 3,600 square feet, the fire-flow requirements in UFC Appendix III-A (Table A-III-A-1) as shown in Figure 3-1 are applicable. UFC fire-flow requirements are based on the type of construction and the size of the building. Implicit in these requirements is the assumption that the fire-flow standards are basically for single-structure fires. That is, they are designed to provide adequate fire suppression capability to contain fires to the structure or block of origin (to prevent a conflagration).

The UFC (Appendix III-A) allows fire chiefs to increase or decrease these fire-flow requirements:

"(a) Decreases. Fire-flow requirements may be modified downward by the chief for isolated buildings or a group of buildings in rural areas or small communities where the development of full fire-flow requirements is impractical.

(b) Increases. Fire flow may be modified upward by the chief where conditions indicate an unusual susceptibility to group fires or conflagrations. An upward modification shall not be more than twice that required for the building under consideration."

Furthermore, a reduction in required fire flow of up to 50 percent, as approved by the chief, is allowed when the building is provided with an approved automatic sprinkler system. Thus, for areas of sprinklered one- and two-family houses, the UFC fire-flow requirement can be as low as 500 gpm.

In the context of the present assessment, it is important to emphasize that the UFC fire-flow requirements are for new construction and do not apply retroactively to existing construction. However, these fire-flow requirements are intended for single-structure fires and thus are not intended to provide fire flows sufficient to suppress an urban/wildland intermix conflagration such as the October 1991 East Bay Hills firestorm.

Figure 3-1
1991 Uniform Fire Code Fire-Flow Requirements

FIRE PROTECTION APPENDIX III-A FIRE-FLOW REQUIREMENTS FOR BUILDINGS

1. SCOPE

The procedure determining fire-flow requirements for buildings or portions of buildings hereafter constructed shall be in accordance with this appendix. This appendix does not apply to structures other than buildings.

2. DEFINITIONS

For the purpose of this appendix, certain terms are defined as follows:

FIRE AREA is the floor area, in square feet, used to determine the required fire flow.

FIRE FLOW is the flow rate of a water supply, measured at 20 psi residual pressure, that is available for firefighting.

3. MODIFICATIONS

(a) Decreases. Fire-flow requirements may be modified downward by the chief for isolated buildings or a group of buildings in rural areas or small communities where the development of full fire-flow requirements is impractical.

(b) Increases. Fire flow may be modified upward by the chief where conditions indicate an unusual susceptibility to group fires or conflagrations. An upward modification shall not be more than twice that required for the building under consideration.

4. FIRE AREA

(a) General. The fire area shall be the total floor area of all floor levels within the exterior walls, and under the horizontal projections of the roof of a building, except as modified in this section.

(b) Area Separation. Portions of buildings which are separated by one or more four-hour area separation walls constructed in accordance with the Building Code, without openings and provided with a 30-inch parapet, are allowed to be considered as separate fire areas.

(c) Type I and Type II-F.R. Construction. The fire area of buildings constructed of Type I and Type II-F.R. construction shall be the area of the three largest successive floors.

5. FIRE-FLOW REQUIREMENTS FOR BUILDINGS

(a) One- and Two-Family Dwellings. The minimum fire flow and flow duration requirements for one- and two-family dwellings having a fire area which does not exceed 3,600 square feet shall be 1,000 gallons per minute. Fire flow and flow duration for dwellings having a fire area in excess of 3,600 square feet shall not be less than that specified in Table No. A-III-A-1.

EXCEPTION: A reduction in required fire flow of 50 percent, as approved by the chief, is allowed when the building is provided with an approved automatic sprinkler system.

(b) Buildings other than One- and Two-Family Dwellings. The minimum fire flow and flow duration for buildings other than one- and two-family dwellings shall be as specified in Table No. A-III-A-1.

EXCEPTION: A reduction in required fire flow of up to 75 percent, as approved by the chief, is allowed when the building is provided with an approved automatic sprinkler system. The resulting fire flow shall not be less than 1,500 gallons per minute.

TABLE NO. A-III-A-1
MINIMUM REQUIRED FIRE FLOW AND FLOW DURATION FOR BUILDINGS

FIRE AREA (square feet)					FIRE FLOW (gallons per minute)	FLOW DURATION (hours)
Type I-F.R. II-F.R. ¹	Type II One-H.R. III One-H.R. ¹	Type IV-H.T. V-One-H.R. ¹	Type II-N III-N ¹	Type V-N ¹		
22,700	12,700	8,200	5,900	3,600	1,500	2
30,200	17,000	10,900	7,900	4,800	1,750	
38,700	21,800	12,900	9,800	6,200	2,000	
48,300	24,200	17,400	12,600	7,700	2,250	
59,000	33,200	21,300	15,400	9,400	2,500	
70,900	39,700	25,500	18,400	11,300	2,750	
83,700	47,100	30,100	21,800	13,400	3,000	3
97,700	54,900	35,200	25,900	15,600	3,250	
112,700	63,400	40,600	29,300	18,000	3,500	
128,700	72,400	46,400	33,500	20,600	3,750	
145,900	82,100	52,500	37,900	23,300	4,000	4
164,200	92,400	59,100	42,700	26,300	4,250	
183,400	103,100	66,000	47,700	29,300	4,500	
203,700	114,600	73,300	53,000	32,600	4,750	
225,200	126,700	81,100	58,600	36,000	5,000	
247,700	139,400	89,200	65,400	39,600	5,250	
271,200	152,600	97,700	70,600	43,400	5,500	
295,900	166,500	106,500	77,000	47,400	5,750	
Greater	Greater	115,800	83,700	51,500	6,000	
"	"	125,500	90,600	55,700	6,250	
"	"	135,500	97,900	60,200	6,500	
"	"	145,800	106,800	64,800	6,750	
"	"	156,700	113,200	69,600	7,000	
"	"	167,900	121,300	74,600	7,250	
"	"	179,400	129,600	79,800	7,500	
"	"	191,400	138,300	85,100	7,750	
"	"	Greater	Greater	Greater	8,000	

¹Types of construction are based upon the Building Code.

Figure 3-2
1991 Uniform Fire Code Fire Hydrant Locations and Distribution

APPENDIX III-B FIRE HYDRANT LOCATIONS AND DISTRIBUTION

1. SCOPE

Fire hydrants shall be provided in accordance with this appendix for the protection of buildings, or portions of buildings, hereafter constructed.

2. LOCATION

Fire hydrants shall be provided along required fire apparatus access roads and adjacent public streets.

3. NUMBER OF FIRE HYDRANTS

The minimum number of fire hydrants available to a building shall not be less than that listed in Table No. A-III-B-1. The number of fire hydrants available to a complex or subdivision shall not be less than that determined by spacing requirements listed in Table No. A-III-B-1 when applied to fire apparatus access roads and perimeter public streets from which fire operations could be conducted.

4. CONSIDERATION OF EXISTING FIRE HYDRANTS

Existing fire hydrants on public streets are allowed to be considered as available. Existing fire hydrants on adjacent properties shall not be considered available unless fire apparatus access roads extend between properties and easements are established to prevent obstruction of such roads.

5. DISTRIBUTION OF FIRE HYDRANTS

The average spacing between fire hydrants shall not exceed that listed in Table No. A-III-B-1.

EXCEPTION: The chief may accept a deficiency of up to 10 percent where existing fire hydrants provide all or a portion of the required fire hydrant service.

Regardless of the average spacing, fire hydrants shall be located such that all points on streets and access roads adjacent to a building are within the distances listed in Table No. A-III-B-1.

TABLE NO. A-III-B-1
NUMBER AND DISTRIBUTION OF FIRE HYDRANTS

FIRE-FLOW REQUIREMENT (gpm)	MINIMUM NO. OF HYDRANTS	AVERAGE SPACING BETWEEN HYDRANTS ^{1,2,3} (Ft.)	MAXIMUM DISTANCE FROM HYDRANT TO ANY POINT ON STREET OR ROAD FRONTAGE ⁴ (Ft.)
1,750 or less	1	500	250
2,000-2,250	2	450	225
2,500	3	450	225
3,000	3	400	225
3,500-4,000	4	350	210
4,500-5,000	5	300	180
5,500	6	300	180
6,000	6	250	150
6,500-7,000	7	250	150
7,500 or more	8 or more ⁵	200	120

¹Reduce by 100 feet for dead-end streets or roads.

²Where streets are provided with median dividers which can be crossed by firefighters pulling hose lines, or arterial streets are provided with four or more traffic lanes and have a traffic count of more than 30,000 vehicles per day, hydrant spacing shall average 500 feet on each side of the street and be arranged on an alternating basis up to a fire-flow requirement of 7,000 gallons per minute and 400 feet for higher fire-flow requirements.

³Where new water mains are extended along streets where hydrants are not needed for protection of structures or similar fire problems, fire hydrants shall be provided at not less than 1,000-foot spacing to provide for transportation hazards.

⁴Reduce by 50 feet for dead-end streets or roads.

⁵One hydrant for each 1,000 gallons per minute or fraction thereof.

3.3.2 Fire Agency Requirements

The District's service area includes 22 fire departments and fire protection districts. A summary of the requirements of all of these agencies is given in Figure 3-3. Under the 1992 California Fire Code, all of these fire protection agencies are subject to the fire-flow requirements of the UFC. We have surveyed these agencies to determine which have implemented the authority to increase fire-flow requirements in high-hazard areas. Oakland has recently proposed a 1,500 gpm fire-flow requirement for new construction in the high hazard hill areas.³ A 1,000 gpm per hydrant fire-flow requirement is consistent throughout all one- and two-family residential areas of Berkeley.⁴

In addition to fire-flow requirements, several jurisdictions, including Berkeley and Oakland, have imposed more stringent building code provisions to enhance fire safety in high fire-hazard areas. In September, 1992, Oakland passed an ordinance⁵ denoting the hill areas east of Highways 580 and 13 as high-hazard fire areas, with more stringent building code provisions. The Oakland high-hazard area also includes the hill areas north of Highway 24 and foothill areas in a band approximately one-half mile wide west of Highways 580 and 13. In August, 1992, Berkeley established a special assessment district⁶ for about 8,000 homes in the Berkeley hills area. A \$50 annual parcel fee has been assessed and the funds will be used for additional fire-safety inspections, improved access and evacuation programs, and enhanced high fire season response. A map of the Berkeley high fire hazard area is shown in Figure 3-4; the Oakland high fire area is as demarcated in the text given in Figure 3-5.

3.3.3 Insurance Services Office (ISO) Fire-Flow Guidelines

The UFC fire-flow requirements, as incorporated into the California Fire Code, are the requirements which apply to new construction throughout the District's service area. For completeness, however, we mention that the Insurance Services Office (ISO) has established fire-flow guidelines, as part of their insurance grading/rating requirements:

"The required fire flow is the rate of flow needed for fire fighting purposes to confine a major fire to the buildings within a block or other group complex. The determination of this flow depends upon the size, construction, occupancy, and exposure of buildings within and surrounding the block or group complex; consideration may be given to automatic sprinkler protection."

"A required fire flow shall be determined at appropriate locations in each district or section or the municipality. The minimum fire flow requirement is 500 gpm and the maximum for a single fire is 12,000 gpm."⁷

Minimum fire flows (500 gpm) apply to low-density residential areas, while the maximum fire flows (12,000 gpm) apply to downtown areas with high-density, multi-story buildings.

In the ISO's 1974⁸ and 1980 editions,⁹ the suggested fire flows for one- and

**Figure 3-3
Fire Agency Requirements**

FIRE AGENCY	RESIDENTIAL FIRE FLOW STANDARD	MINIMUM HYDRANT REQUIREMENT	HIGH HAZARD AREA DESIGNATED?	SPECIAL ASSESSMENT ZONE?
Alameda Fire	2,500 gpm out of any 2 hydrants (implied 2 hr duration)	1,500 gpm	No	No
Albany Fire	UFC	500 gpm	No	No
Berkeley Fire	UFC	1,000 gpm	Yes - Building Code Enhancements ¹	Yes ¹
Castro Valley Fire Protection District	UFC (NOTE: In process of consolidating with Eden and following those requirements)	1,250 gpm	Yes - Wildland-Urban Interface designated "State Response Area"	Not Yet
Contra Costa County Fire Protection District	UFC	1,000 gpm	No ²	No
Crockett Fire	Minimum 2,000 gpm flowing from 2 hydrants simultaneously [with no duration requirement]	n.a.	Yes ³	Yes ³
Dougherty Regional Fire Authority	UFC	1,000 gpm	No	No
Eden Consolidated Fire Protection District	UFC ⁴	1,250 gpm	No ⁵	Not Yet

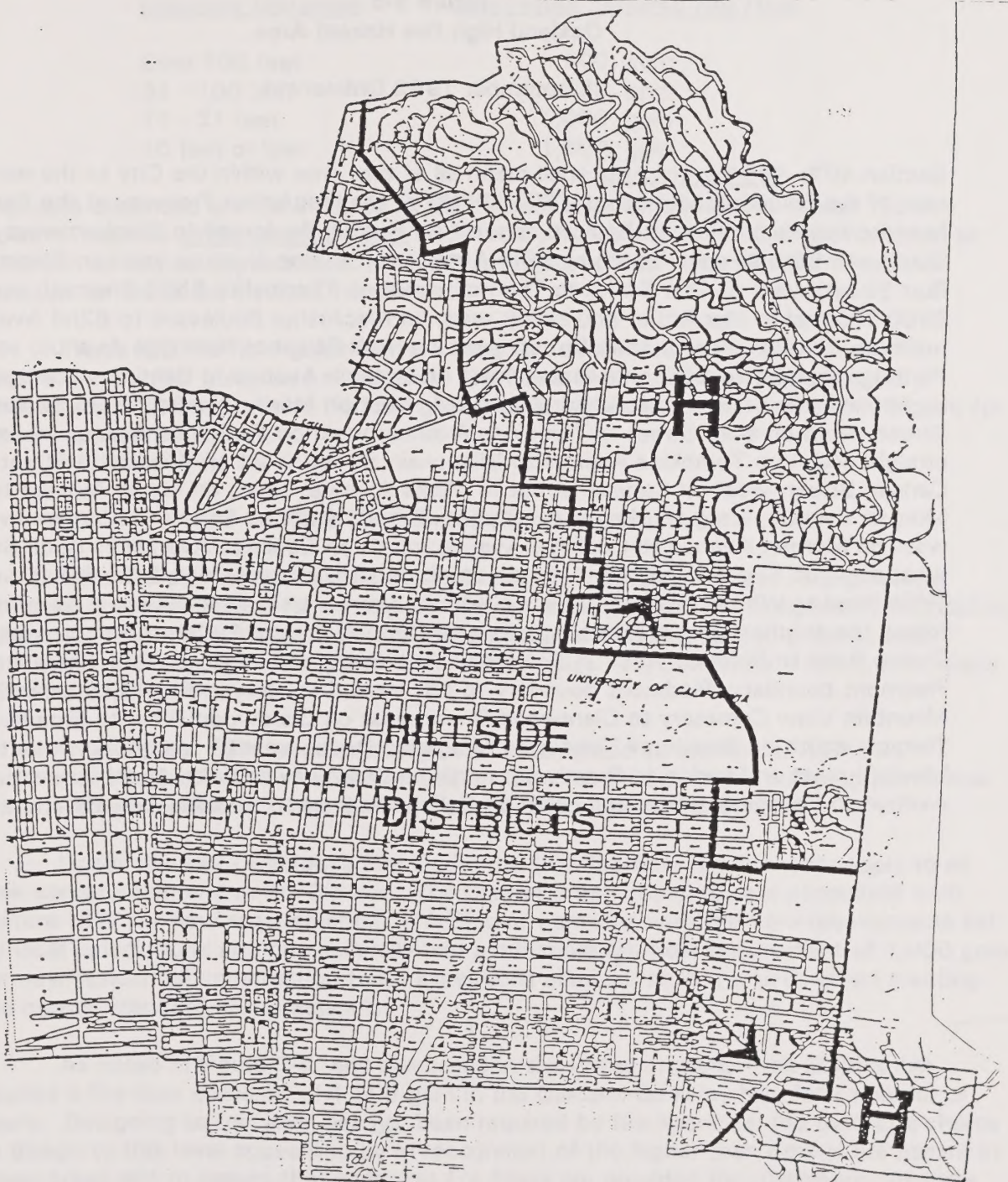
FIRE AGENCY	RESIDENTIAL FIRE FLOW STANDARD	MINIMUM HYDRANT REQUIREMENT	HIGH HAZARD AREA DESIGNATED?	SPECIAL ASSESSMENT ZONE?
El Cerrito Fire	UFC	1,000 gpm (<u>new</u> hydrants)	Yes - Wildland-Urban Interface designated by City Council	No
Emeryville Fire	UFC	n.a. (all are over 1,500 gpm)	No	No
Fairview Fire Protection District	UFC	1,000 gpm	No	No
Hayward Fire	1-2 Family Residential Areas = 1,500 gpm for 2 hours	n.a.	Yes - Wildland-Urban Interface	No
Kensington Fire	UFC	1,000 gpm	Yes - Border with East Bay Regional Parks	No
Moraga Fire Protection District	UFC	1,000 gpm	No	No
Oakland Fire Protection District	UFC	n.a.	Yes ⁷	Yes ⁷
Orinda Fire Protection District	UFC	n.a.	No ⁸	No
Piedmont Fire	UFC	1,000 gpm	No ⁹	No
Pinole Fire	UFC	1,000 gpm	No	No

FIRE AGENCY	RESIDENTIAL FIRE FLOW STANDARD	MINIMUM HYDRANT REQUIREMENT	HIGH HAZARD AREA DESIGNATED?	SPECIAL ASSESSMENT ZONE?
Richmond Fire	UFC	1,500 gpm	Yes - "Fire Physical Constraint Area" where bldg code constraints on <u>new</u> construction	No
Rodeo Hercules Fire Protection District	UFC	Residential = 1,000 gpm Commercial = 1,500 gpm	Yes - City Code = Class A roofing required and siding "suggestions" (all sprinklered)	No ¹⁰
San Leandro Fire	UFC	n.a.	No	No
San Ramon Valley Fire Protection District	UFC	1,000 gpm	Yes - Wildland-Urban Interface where non- combustible roofing required	No
Other Jurisdictions:				
Los Angeles City	Internal ⁶	Internal ⁶	No	No
Santa Barbara City Fire Department	500 gpm (No duration requirement)	n.a.	No	No
Santa Barbara County Fire Department	Internal ¹¹	500 gpm	No	No

Figure 3-3 Footnotes:

- ¹ Berkeley Adopted Resolution #56568-NS formed the Berkeley Hills Fire Prevention and Preparedness Assessment District. This program involves aspects of increased high fire response, brush clearance, inspection, and access and evacuation programs. No increased fire flow is required.
- ² Frank J. Boyle, Supervising Inspector of the Contra Costa County Fire Protection District suggests that a future ordinance may make sprinklers mandatory in new construction.
- ³ No wildland-urban interface high hazard area designated. However, an area containing 20 - 25,000 gallon oil tanks are designated as a high hazard area. A booster pump fee is assessed in the area.
- ⁴ In the process of designing a residential sprinkler ordinance and passing the 1991 UFC. Currently follows an unwritten residential fire flow requirement calculated by using a 2,000 gpm base which is subjectively lowered for fire resistant roofing and decreased by 250-500 gpm for sprinklers. The duration requirement is 2 hours.
- ⁵ When consolidated with Castro Valley Fire Protection District will contain its "State Response Area" located at the wildland-urban interface with the Parks Region.
- ⁶ Low Density Residential: requires 2,000 gpm from 3 adjacent fire hydrants flowing simultaneously. High Density Residential and Neighborhood Commercial: 4,000 gpm from 4 adjacent fire hydrants flowing simultaneously.
- ⁷ Data from Oakland City Manager's Office; p.17, October 6, 1992; Established Minimum Fire Flow Standards: The Fire Chief has published the minimum acceptable fire flow standards for all hydrants located within the City's designated Fire Hazard Area. For all areas below Highway 13, the fire flow from a hydrant should be at least 1,000 gpm; for areas above Highway 13, the standard is 1,500 gpm.
- ⁸ Orinda is considering changes in building standards - eg. roof standards, sprinkler requirements, etc. in high hazard wildland-urban interface areas.
- ⁹ Wildland-urban interface building and vegetation controls are currently proposed before the City Council.
- ¹⁰ Marston Ranch area has separate fire flow pump which the building owners in that area paid for.
- ¹¹ The fire flow required for single family dwellings in Urban and Rural developed neighborhoods is 750 gpm for 1 hour. The fire flow required for multi-unit residential buildings or mobile homes is 1,500 gpm for 1 hour.

Figure 3-4
Berkeley High Fire Hazard Area



*Map located in draft construction standards contained in the City of Berkeley Fire Hazard Mitigation Plan; October 20, 1991 East Bay Hills Conflagration. February 25, 1992, p. 46.

Figure 3-5
Oakland High Fire Hazard Area

(September 1992 Ordinance)

Section 407: Fire-Hazard Area shall mean all of that area within the City to the north and east of the following boundaries: BEGINNING at the MacArthur Freeway at the San Leandro boarder to Foothill Boulevard; west on Foothill Boulevard to Stanley; west on Stanley to 98th Avenue; south on 98th Avenue to Stearns Avenue; west on Stearns to Burr Street; west on Burr Street to Thermal; west on Thermal to 8500 Thermal; south at 8500 Thermal to MacArthur boulevard; west on MacArthur Boulevard to 82nd Avenue; north on 82nd Avenue to Utah Street; west on Utah Street to Partridge Avenue; south on Partridge Avenue to Outlook Avenue; west on Outlook Avenue to Seminary Avenue; south on Seminary Avenue to MacArthur Boulevard; west on MacArthur Boulevard to Buell Street; north on Buell Street to Tompkins Avenue; west on Tompkins Avenue to End; straight line from Tompkins Avenue to Wisconsin Street; west on Wisconsin Street to Carlsen Street; west on Carlsen Street to Maple Avenue; south on Maple Avenue to Morgan Avenue; west on Morgan Avenue to Barner; south on Barner to Morgan Avenue; west on Morgan Avenue to Coolidge Avenue; north on Coolidge Avenue to Alida Street; west on Alida Street to Lincoln Avenue; south on Lincoln Avenue to Tiffin Road; west on Tiffin Road to Whittle Avenue; west on Whittle Avenue to Fruitvale Avenue (Dimond Park); follow the southern and western boundary of Dimond Park to El Centro Road; west on El Centro Road to Dolores; west on Dolores to Park Boulevard; north on Park Boulevard to Piedmont boundary; Piedmont boundary to Mt. View Cemetery; northern boundary of Mountain View Cemetery to Clarewood Drive; west on Clarewood Drive to Broadway Terrace; south on Broadway Terrace to Margarido Drive; west on Margarido Drive to Lawton; west on Lawton to Broadway; north on Broadway to Keith Avenue; west on Keith Avenue to College Avenue; and north on College Avenue to Berkeley boundary.

two-family dwellings not exceeding two stories are as follows:

<u>Exposure Distances</u>	<u>Suggested Required Fire Flow</u>
Over 100 feet	500 gpm
31 - 100 feet	750 gpm
11 - 31 feet	1,000 gpm
10 feet or less	1,500 gpm

Exposure distances are the distance to the nearest adjacent structure. These ISO fire flows all assume single structure fires with fire hydrants within 1000 feet (measured as hose can be laid by apparatus) of the front of the structure.⁹ The minimum required duration for these fire flows is two hours.

These ISO fire-flow guidelines are roughly comparable to the UFC fire-flow requirements. ISO guidelines allow lower fire flows (500 gpm) for widely-spaced structures, while they require (for rating purposes) higher fire flows (up to 1,500 gpm) for closely-spaced structures.

3.3.4 The District's Fire-Flow Practices

Over the past several decades, the District has developed a set of Engineering Standard Practices (ESPs) for use by the District in planning and building water distribution systems. These ESPs address a wide range of topics including design criteria, cost estimation, drafting, surveying, and many other topics. As of February 1990, there were 99 current ESPs.¹⁰

Two District ESPs address design elements related to fire flows. ESP 492.1¹¹ specifies minimum fire flows and pipe sizes. ESP 492.2¹² addresses pumping plants and water storage facilities. These ESPs are summarized in Figure 3-6.

Under the 1992 California Fire Code, the UFC fire-flow requirements apply to all new construction within the District. The District's ESP standards are consistent with current UFC fire-flow requirements. The District complies with fire-flow requirements set by local jurisdictions and has generally had a minimum fire-flow requirement of 1,000 gpm for new residential construction (with exceptions allowed, as in the UFC, when meeting the normal standard is impractical).

As noted in Figure 3-6, and discussed in the Phase I report,¹³ the District has applied a fire-flow standard of 1,500 gpm in the Oakland-Berkeley hills for a number of years. Designing to this level has not been required by fire agencies; the District's choice to design to this level appears to be in recognition of the higher than normal fire hazard in these areas and to ensure that adequate fire flows are provided for customers. In some other areas, the District also has designed water distribution systems to higher standards. In Blackhawk, for example, the water system has been designed to a 2,500 gpm fire-flow standard, corresponding to the UFC fire-flow required for the large size houses prevalent in Blackhawk.

FIGURE 3-6
DISTRICT STANDARD PRACTICES ^{1,2}

CURRENT STANDARDS	FIRE FLOW	PIPE SIZING	PUMPING PLANTS	STORAGE
EBMUD 1985	Specified by fire agency. If fire agency does not specify fire flow, then use a minimum of 1,000 gpm for 2 hrs; 500 gpm allowed for extensions to a single premise or small development if minimum fire flows cannot be met without significant upgrades, and the applicant and firefighting agency are so notified. (1,500 gpm for 2 hours in Oakland-Berkeley Hills).	6 inch minimum, 4 inch allowed in cul de sac if no hydrants needed. 20 psi residual for fire flow + max. demand.	Pump to meet 1.5 times Maximum Day Demand ($\leq$ 16 hour recovery period). At least one spare pump. In larger zones, try to plan for more than one pumping plant in separate parts of the PG&E grid.	1.5 times maximum day demand plus fire flow x duration. Minimum storage for any pressure zone is 300,000 gallons.

¹ Flow requirements and pipe sizing are indicated in ESP 492.1, Water Main Planning Criteria.

² Pumping plant and storage requirements are indicated in ESP 492.2, Distribution Reservoir and Pumping Plant Planning Criteria.

In a few, small portions of the District's Service Area, low-pressure service is provided under Section 8A of the District Regulations.¹⁴ In such areas, the fire-flow assumption for sizing mains is determined under the unusual conditions in Procedure GM-027.¹⁵ Such special fire-flow requirements are allowed within the UFC under the provision for decreases in fire flows where the development of full fire-flow requirements is impractical (UFC, Appendix III-A).

The District's current ESP (492.1) which addresses fire flows states in Section C.2 that:

"For new commercial, industrial, or other development, and new residential development not included above, the fire flow assumption for planning extensions and system improvements will be determined on a case-by-case basis considering the specific needs of the premises to be served and the guidelines published by the Insurance Services Office."

Under the provisions of the 1992 California Fire Code, which extends the fire-flow requirements of the UFC to all occupancies in California, it appears that this ESP should be revised to reflect UFC fire-flow requirements, rather than ISO fire-flow guidelines.

At present, the District does not systematically collect and maintain data on the fire flow performance capability of the existing system. We suggest that a fire flow data base, based on fire flow tests and hydraulic modeling, be collected on a systematic, District-wide basis. Such data would be helpful for emergency planning purposes and in planning repairs, replacements, and upgrades to the existing distribution system. The District's hydrant testing program currently in development should be fully implemented.

3.3.5 Other Water Agency Fire Flow Practices

For comparison to District practices, the practices of several other California water agencies have been reviewed. Information on these agencies' fire flow standards and practices and other related policies is summarized in Figure 3-7. This Figure contains information on: 1) fire flow standards followed, 2) whether or not different fire flow standards are applied to high hazard areas, 3) how fire flows are met (pumping, storage, both), 4) pumping plant sizing criteria, and 5) water storage criteria, where available. The water agencies were selected primarily because they have high hazard residential hill areas with fire hazards roughly comparable to those in the District's high hazard areas.

As shown in Figure 3-7, other water agencies generally follow fire department fire flow requirements, although a few, including EBMUD, have internal requirements which may augment fire department requirements. No agencies other than EBMUD acknowledged having higher fire flow requirements for high hazard areas, although two agencies noted that sprinkler systems are required (by fire agencies) in designated high hazard areas. Water agencies typically meet fire flow requirements by storage or by a combination of storage and pumping. Pumping plants for pumped pressure zones are generally sized to replace maximum daily water demand from customer use. Water storage requirements for sizing reservoirs appear to be set primarily based on maximum

Figure 3-7
Water Agencies' Fire Flow Practices

WATER AGENCY	FIRE FLOW (FF) STANDARD FOLLOWED, Fire Dept. (FD) or INTERNAL	DIFFERENT FF STANDARD FOR HIGH HAZARD (HH) AREAS?	HOW FF STANDARD IS MET (STORAGE, PUMPING OR BOTH)	PUMPING PLANT CRITERIA	STORAGE CRITERIA
Alameda County Water District (Fremont, CA)	FD	No	Storage or pumping	pump to meet fire flow	1.5 x maximum daily demand + fire reserve
California Water Service Co. (San Jose Office)	Public Utilities Commission General Order 103	No	Depends on location	Replenish maximum day demand in 12 to 16 hours	0.5 x maximum daily demand + fire reserve
Contra Costa Water District	FD or Internal (1,000 gpm)	No	Storage	Enough to replenish maximum daily demand (w/ largest pump out of service)	Operational volume + minimum average daily demand (for emergency reserve) + Fire Reserve
Goleta Water District (Santa Barbara County)	FD	No (supplemental sprinklers required)	Storage	To replenish maximum daily demand	Peak Day Demand + Operating Storage Consideration + Fire Reserve
City of Hayward	FD	No	Both	not available	not available
Los Angeles Dept. of Water and Power	FD	No	Both	Pump to replace 115% of residential maximum daily demand, plus average daily demand for other uses, excluding fire flows	200,000 gallons per cfs (cubic feet per second) of maximum day demand. Emergency storage of 540,000 gallons or 100,000 gallons per cfs, with exceptions for pressure zones below 1.5 cfs mean annual demand
Marin County Water District	FD	No	Storage	Pump to replenish average summer daily consumption in 8 hours	Two Average Summer Days Demand (Fire Reserve included in that)
Santa Barbara City Public Works	FD	No	Depends on Location	Replace maximum daily demand (smaller zones 500-600 gpm)	Approximately 2 x maximum daily demand
Santa Cruz City	FD	No	Both	n.a.	n.a.
Santa Rosa City Utilities	FD	No (interior and roof sprinkler system required)	Storage	1500 gpm for 1-2 hours	Fire Reserve + Daily Demand (based on the number of units)
EBMUD	FD and Internal (ESP 492.2)	YES	Storage	Pump to meet 1.5 times maximum day demand	operating band plus 1.5 times maximum day demand plus fire reserve (fire flow times duration)

daily demand for customer use; most agencies add a separate storage component for fire fighting. Some other agencies, including Los Angeles Water and Power, include fire fighting reserves in a general emergency reserve which is also designed for temporary pumping or supply interruptions.

Los Angeles' fire flow standards are unique in two regards. First, standard for low density residential areas are expressed as 2,000 gpm from three adjacent hydrants flowing simultaneously.¹⁶ Other agencies, including the District, consider flows (1,000 or 1,500 gpm) from single hydrants for one- and two-family residential areas. Second, Los Angeles has explicit fire flow requirements for entire pressure zones, while the other agencies only consider single-site fire flows. Los Angeles' pressure zone fire flow requirements are to be figured during the six-hour period when the system's demand and supply capabilities will result in the most vulnerable situation (presumably the hours on the maximum day around the peak hour). The pressure zone standards are:¹⁶

3,000 gpm for large (over 2000 acre systems), newer systems and all systems having multiple family dwelling units three stories or higher.

2,000 gpm for systems having more than 500 acres but less than 2,000 acres.

1,500 gpm for systems having less than 500 acres and with only single-family dwelling units.

We note that these standards, which are the most recent published by Los Angeles, conflict with the current fire flow requirements of 2,000 gpm from three adjacent hydrants. These entire pressure zone standards are included because of their relevance to discussions about acceptable performance for water systems in fire emergencies.

Fire flow practices in Los Angeles are of particular interest because Los Angeles has numerous high hazard residential hill areas. Following the 1991 East Bay Hills firestorm, it was reported that Los Angeles had six-hour fire flow durations in such areas, compared to the normal UFC two-hour fire flow duration.¹⁷ However, analysis of the design criteria used by the City of Los Angeles Department of Water and Power indicates that imprecise, misleading comparisons have been made. Water storage requirements for Los Angeles are "at least 200,000 gallons of storage for each cfs (cubic foot per second) of maximum-day system demand."¹⁸ All of this storage need not be within the pressure zone; some of this storage can be provided in a higher zone, if it is more economical to do so. Of the total storage, the larger of 540,000 gallons or 100,000 gallons per cfs of system maximum-day demand must be kept in reserve for emergency use.¹⁸ 540,000 gallons is six-hours of fire flow at 1,500 gpm. However, this "reserve for emergency use" is a combination of reserve for normal use, in the event of pumping plant failures or other water supply interruption and firefighting emergency needs. Therefore, these figures cannot be compared directly with the District's fire reserve water storage because the District considers separate reserves for customer use and fire use. For a typical 500,000 gallon reservoir in the East Bay Hills, 208,000 gallons are emergency reserves while 180,000 gallons are a firefighting reserve. Thus, the total storage for "emergency use" is 388,000 gallons, or about 72% of the Los Angeles standards. In making comparisons, however, it

is important to note that the fire threat is significantly higher in the Los Angeles area than in the District's service area because of the much higher number of days per year in Los Angeles of extremely hot, dry, windy conditions.

Furthermore, the Los Angeles storage requirements have exceptions for small pressure zones where the mean annual demand does not exceed 1.5 cfs (about 670 gallons per minute). In these cases, which correspond to the smaller pressure zones higher in the East Bay Hills, smaller tanks of 50,000 to 200,000 gallons may be considered a viable alternative to the tank sized in accordance with the normal criteria if a major reliable source is available. Los Angeles' pumping plant design criteria are 115% of the system's residential maximum day demand plus the average daily demand imposed on the system by all other demands, excluding fire flow. For residential pressure zones, these criteria would allow pumping plants to be sized to replace the maximum daily demand in about 20 hours, which is a less-stringent requirement than the District's 16-hour replacement of maximum daily demand.

The practices and methods by which the major water agencies surveyed provide fire flows and fire flow durations vary in detail (and all agencies allow exceptions for special circumstances). Most agencies rely heavily on storage to meet emergency demands, while some rely more heavily on pumping. On balance, however, the combination of design criteria and practices result in roughly similar design fire flow capabilities among these water agencies.

3.4 OTHER RELATED POLICIES

3.4.1 New Service and Repairs To Existing System

District policies regarding the cost of extending mains for new water service are outlined in Section 4 of the Regulations Governing Water Service to Customers.¹⁴ As specified in these regulations, the applicants for water service shall pay the full costs of the facilities required to provide the service:

"In general, whenever extensions of a water main within the District boundaries is required because a principal part of premises to be served does not lie along an available water main with adequate capacity and proper pressure, the extension will be installed after an agreement has been executed by the applicant and the District for payment of all applicable charges. The manner of determining the charges is set forth in this section and is based on the policy of the District that applicants for water service shall pay the full cost of facilities required to provide the service. The charges shall be as described in the Schedule of Rates and Charges."¹⁴

Normal maintenance and repairs to the existing water distribution system are made and paid for by the District (i.e., the costs are covered by the District's entire rate-paying customer base). The current District guideline (as expressed in ESP 492.1 "Water Main Planning Criteria) is that such repairs are made to return the system to the performance capability of the system when it was built (the "as-built" or original design standard):

"For existing development, the fire-flow assumption for replacement of mains and system improvements will be to maintain, and if necessary to restore, the fire flows available when the water mains were new."¹⁹

However, in some cases, this repair to the as-when-built standard appears to be superseded by minimum pipe size standards outlined elsewhere in ESP 492.1. For example, Section D.1.a. of ESP 492.1 establishes a minimum distribution mains size of 6 inches for low- and medium-density residential areas (with exceptions as specified in Section D.1.d.). This minimum size requirement, as well as recent District practice indicates that current District policy is to replace old 4-inch mains with at least 6-inch mains when main replacement is required. Recent District practice²⁰ differs from the written policy stated in ESP 492.1, which should be revised to reflect current practices. Current practice²⁰ is to replace short segments with similar pipe when leaks or other problems require replacement of a few feet of pipe. However, when repair considerations (numerous leaks in a given area) dictate that a significant replacement of pipe is to be made, then the replacement is treated by the planning department as if the replacement were new construction and the same design criteria are used for sizing pipe. In particular, a seismic vulnerability review is included and if the replacement area is at high seismic risk (fault crossings, landslide areas, soft soils, etc.) then lined steel pipe (minimum size 8") which is more seismically resistant is installed.

At present, however, it is not District practice to systematically upgrade older portions of the distribution system because they do not meet current design standards. Furthermore, older portions of the District's distribution system have lower fire flow capabilities than as-designed (because of degradation of pipe with time); however, the District does not have a systematic policy to evaluate and repair such sections to the as-designed standard.

Another area where recent District practice appears to conflict with the as-when-built standard is temporary fixes. For example, the Thornhill regulator was installed in 1982 after a landslide destroyed a distribution main. The "temporary" fix of installing the regulator was intended to be for only a few months. In practice, however, this "temporary" fix has lasted 10 years, with a corresponding diminution of fire-flow capability below the original as-built standard. Clarification of the District's repair and replacement policy, including explicit limits on temporary fixes, should become an important priority.

A summary comparison between the District's repair and replacement practice and those of several other water agencies is given in Figure 3-8.

3.4.2 Emergency Response and Service Restoration

Effective disaster planning to improve emergency preparedness and to assure maintenance of critical District functions during disasters is included in the Board's Mission Statement and Corresponding Goals, Priorities and Objectives. Specific emergency authorities and responsibilities are partially outlined in existing emergency operations plans of the District for the Wastewater Division.²¹ Emergency authorities, responsibilities, and policies are currently undergoing intensive review and revision under Task 5 of Phase II of this emergency response assessment (Enhance Emergency Planning and Emergency

**Figure 3-8
Water Agency Upgrade Policies**

WATER AGENCY	UPGRADE POLICY for older portions of the water system	MINIMUM PIPE SIZE¹ (NEW PIPE)
California Water Service	replacement for maintenance/repair purposes	6"
Contra Costa Water District	priorities based on the number of leaks and complaints	6"
Goleta Water District (Santa Barbara County)	very minimal plan to replace a small portion of early 1950s pipe	6"
Los Angeles City Dept. of Water and Power	replacing all pipe laid prior to 1925	6"
Marin County Water District	upgrade fire flows using recommended projects provided by fire districts served	6"
Santa Barbara City Public Works	spend roughly \$2 million per year based on 100 year replacement cycle	8"
Santa Cruz City	"if it breaks, we fix it"	6"
Santa Rose City Utilities	\$1 million to \$2 million per year spent to upgrade 2-4" pipe to 8"	8"
EBMUD	generally repair to as-when-built, but replace to current standards when required for maintenance reasons; priorities based on the number of leaks and complaints. \$6-8 million per year for distribution system pipe replacements	6"

¹ All agencies have exceptions for short lengths of pipe, without hydrants, in cul-de-sacs.

Response). Such policies will be specified in detail in the District's Emergency Operations Plan² currently under major revision as part of Task 5 of Phase II.

The District's practices for service restoration after emergency disruptions appear to be governed primarily by operations experience and judgement, rather than by formal, written District policies. As discussed in Section 3.1 of this chapter, the draft Emergency Operations Plan does include explicit service restoration priorities as well as response and recovery objectives. In addition, proposed service level goals for restoration of service after a major earthquake were outlined in a recent District report.²² However, these goals have not been adopted as formal District policy.

Chapter 3 Endnotes:

1. East Bay Municipal Utility District, Board of Directors Resolution No. 32580, Adopting the District Mission Statement and Corresponding Goals, Priorities and Objectives, February 25, 1992.
2. East Bay Municipal Utility District, Emergency Operations Plan, Draft, December 12, 1992.
3. East Bay Hills Firestorm Response Assessment, Phase I Final Report; VSP Associates, Inc.; G&E Engineering Systems, Inc.; and Barbara Foster Associates; July 15, 1992, p. 3-11.
4. Personal Communication, C. Beacham, City of Berkeley Fire Marshal, to S. Clark, August 26, 1992. Supported by City of Berkeley Ord. 6052-NS subsection 1, 1991 (Ch. 19.48.020 Berkeley City Code (1991)).
5. Oakland City Ordinance #11485 C.M.S., 1992.
6. City of Berkeley Adopted Resolution #56568-NS, 1992.
7. Grading Schedule For Municipal Fire Protection, Insurance Services Office, 1974.
8. Guide for Determination of Required Fire Flow, Insurance Services Office, December 1974.
9. Fire Suppression Rating Schedule, Insurance Services Office, 1980.
10. ESP 001, Index, EBMUD Engineering Standard Practice, effective February 7, 1990.
11. ESP 492.1, Water Main Planning Criteria, EBMUD Engineering Standard Practice, effective October 17, 1985.
12. ESP 492.2, Distribution Reservoir and Pumping Plant Planning Criteria, EBMUD Engineering Standard Practice, effective May 1, 1979.

13. East Bay Hills Firestorm Response Assessment, Phase I Final Report; VSP Associates, Inc.; G&E Engineering Systems, Inc.; and Barbara Foster Associates; July 15, 1992, p. 3-12.
14. East Bay Municipal Utility District, Regulations Governing Water Service to Customers of the East Bay Municipal Utility District, in "Water Service: Regulations and Schedule of Rates & Charges," 1992.
15. East Bay Municipal Utility District, Procedure GM-027, Low Pressure Service, Organization Manual.
16. Division 9, Los Angeles City Fire Code §57.09.06.
17. J. Jarf, Los Angeles Department of Water and Power, quoted in "Firestorm: The Week the Hills Burned" Oakland Tribune Special Edition, December 2, 1991.
18. Los Angeles Department of Water and Power, Water Engineering Design Division, Planning Section, "Pump Systems Design Criteria" 1979.
19. ESP 492.1, Water Main Planning Criteria, EBMUD Engineering Standard Practice, effective October 17, 1985.
20. East Bay Municipal Utility District, recent practices, personal communication from Leo O'Brien December 11, 1992.
21. East Bay Hills Firestorm Response Assessment, Phase I Final Report; VSP Associates, Inc.; G&E Engineering Systems, Inc.; and Barbara Foster Associates; July 15, 1992, Chapter 4.
22. East Bay Municipal Utility District, Levels of Service for Post Earthquake Water System Performance, February 19, 1992.

4.0 DISTRIBUTION SYSTEM CURRENT PERFORMANCE AND POSSIBLE FIRE FLOW UPGRADES

4.1 INTRODUCTION

This chapter addresses two main topics for pressure zones in the October 1991 firestorm area:

1. fire flows in the current distribution system, and
2. a range of alternative upgrades to the existing system.

Hydraulic models have been developed for nine pressure zones: A13B (Berkeley Hills); A11A (Gwin); A9B (Strathmoor); A7B (Amito); A5A (Summit); B13Aa (Hilltop); B11A (Pinehaven); B9A (Thornhill); B7A (Joaquin Miller). Similar hydraulic modeling has also been done for the B4Aa (Broadway Terrace) and B5A (Dingee) pressure zones; these results have been incorporated into separate District reports. Using these hydraulic models, the current fire flow performance of these zones has been evaluated and a range of alternative upgrades has been considered.

In Section 4.1, each hydrant in the area modeled is analyzed to determine if it can provide the following fire flow rates: 1,500 gpm (all areas east of Highway 13), or 1,000 gpm (limited portion of B7A west of Highway 13). The 1,500 gpm fire flow rate has been recently proposed for new construction in this high-hazard area by the Oakland Fire Department. The 1,000 gpm fire flow rate is the current UFC fire flow rate for new construction in one- and two-family residential areas. Under the UFC, current fire flow requirements are not applied retroactively to previously built systems. However, to assess the current performance of the distribution system in this area, we compare the performance with these standards for new construction.

Results of this hydraulic modeling of existing hydrant fire flow rates are summarized in Table 4-1. Of the 267 hydrants modeled, 77% meet the 1,500 or 1,000 gpm standard for new construction, 1% meet the standard at a marginal residual pressure, and 22% do not meet these fire flow rates.

Section 4.1 contains detailed hydraulic modeling results for each hydrant in the area modeled. Each hydrant is classified into one of three levels: meets fire flows levels equal to current standards for new construction; meets fire flow levels with marginal residual pressure; or does not meet fire flow levels. For hydrants which do not meet fire flow levels, the actual fire flows available at the hydrant are presented. For each hydrant that does not meet the fire flow levels, alternative upgrades are developed, and tested in the hydraulic models. Hardware upgrades are then selected such that fire flows at each hydrant are increased to the stated levels. Replacement lengths of pipe are described, by street location, including both the old pipe to be removed, and the new type of pipe to be installed.

Table 4-1
Summary Statistics - Nine Pressure Zones-As-Built Condition

Pressure Zone	Pipe Length in Total Zone (Miles)	Pipe Length in Hydraulic Model (Miles)	Services in Hydraulic Model	Total Hydrants in Hyd. Model	Meet Flow @ 20 psi	Meet Flow @ 10 psi	Do Not Meet Flow
A13B Berkeley Hills	0.9	0.9	1	6	6	0	0
A11A Gwin	1.8	1.8	139	16	15	0	1
A9B Strathmoor	5.5	5.5	465	42	40	1	1*
A7B Amato	6.5	6.5	365	51	36	1	14**
A5A Summit	27.4	6.8	246	27	27	0	0
B13Aa Hilltop	1.0	1.0	33	9	2	0	7
B11A Pinehaven	2.1	2.1	173	15	11	0	4
B9A Thornhill***	10.7	5.8	478	38	12	1	25
B7A Joaquin Miller	28.5	11.4	1,060	63	56	0	7
TOTALS	84.4	41.8	2,960	267	205	3	59
				100%	76.7%	1.1%	22.1%

Notes:

* Nearby hydrant in next pressure zone provides combined fire flow over 1,500 gpm

** Nearby hydrant in next pressure zone provides combined fire flow over 1,500 gpm at one hydrant individually not meeting fire flow

*** Feed into B9A Thornhill limited by pipes in B11B Carisbrook pressure zone.

The results presented in Section 4.1 address only fire flow rates (hydrant flows in gpm). In Section 4.2, an additional series of analyses is presented for the Amato A7B pressure zone. These analyses explore a range of upgrade alternatives to improve fire flow durations and to enhance the zone's capability to support concurrent multiple front fire suppression efforts. These Amato zone analyses were conducted as examples to explore the costs and effectiveness of a range of alternatives in improving fire flow duration and multiple front capability.

4.1 HYDRAULIC ANALYSIS: FIRE FLOW RATES

One hydraulic model has been developed for each of nine pressure zones in the October 20, 1991 firestorm area. Each model is analyzed using the KYPIPE mathematical model, developed at the University of Kentucky, which is considered an industry standard. The hydraulic models include junctions at each hydrant location. Additional junction nodes are located at changes in pipe diameter and pipe material. All pipes with hydrants are modeled.

Pressure zones that are modeled in their entirety are: A13B; A11A; A9B; A7B; B13Aa; and B11A. The B9A pressure zone is completely modeled for the northern Thornhill portion (the southern Forestland portion is located outside the firestorm area and is not modeled; it was split off from the Thornhill portion due to a landslide in 1982 and is now hydraulically unconnected). The A5A pressure zone is modeled in, and near, the firestorm area, and also includes the feed from the Summit East pumping plant. The B7A pressure zone is modeled in, and near, the firestorm area, and also includes the feed from the Montclair pumping plant and Montclair reservoir. A portion of the B11B pressure zone is modeled, to analyze the B11B source of water from the Forest Park reservoir to the Thornhill pressure regulator.

The models use friction coefficients considered best estimates for the kind, diameter and age of the pipes in each zone. Verification of these models should ideally be based upon a series of fire flow tests. Due to District scheduling priorities, such fire flow tests have not been performed in the nine pressure zones presented in this report. Instead, friction coefficients used in these models are based upon a hydraulic model calibration effort recently performed by the District, for the B5A Dingee pressure zone. In that effort, the District had several hydrants flowed; and results from these hydrant tests were used to calibrate a hydraulic model of the B5A zone.

The B5A zone includes mostly the same types and vintages of pipe as in the nine pressure zones presented in this report; therefore, use of the B5A friction coefficients is probably a good estimate, overall, of pipe conditions in the other pressure zones. However, possible unusual levels of tuberculation, closed valves, and similar localized problems are not incorporated in the current modeling of the nine pressure zones. Therefore, results presented in this report for the nine pressure zones should be considered as indicative: actual fire flow tests within these zones may warrant changes in results. We recommend that the District perform such fire flow tests to confirm the analysis results prior to implementing the hardware upgrade alternatives presented in this report. However, the chosen friction coefficients should provide reasonable results, on a whole.

The friction coefficients are provided in Table 4-2.

A fire flow level of 1,500 gpm, with one hydrant flowing at a time, was used as the flow criteria in all areas, except the parts of the B7A Joaquin Miller pressure zone west of Highway 13, where the fire flow level modeled was 1,000 gpm. A pressure zone was considered adequate if residual pressures in the zone were at least 20 psi, while flowing the hydrant at the required flow rate. As noted in the text, static (normal water use) pressures were checked when considering re-zoning alternatives, and limited to 120 psi, unless additional care is taken to add pressure regulators in higher pressure areas. When upgrades were required, candidate pipes to be replaced were generally those with highest head losses and velocities. Pipe upgrades were chosen to minimize total length of replaced pipe.

The above fire flow levels (1500 gpm / 1000 gpm) were discussed with the Technical Advisory Panel (TAP), including the Oakland Fire Chief, and a representative for the Berkeley Fire Chief. It was agreed that these fire flow levels were appropriate for providing adequate flows for fires usually encountered. These fire flow criteria are for single structure fires.

The fire flow duration was assumed to be 2 hours. All of the nine pressure zones meet this duration requirement, using storage, in accordance with District Engineering Standard Practice 492.2 (effective January 1, 1985). [Pressure zone B9A meets this duration using storage within B9A and B11B.] Other possible levels of fire flows and durations, as well as the possibility of multiple concurrent fire flows, were extensively discussed with the TAP and the District. These alternate criteria are discussed in Section 4.2.

Concurrent with the fire flows is a maximum day, peak hour, normal consumption demand. The data to develop the maximum day, peak hour, normal consumption demand is based on the highest recorded actual demands, using EBMUD WCIS data, for the 21 month period from January 1990 through September 1991. At the start of the fire, each reservoir is assumed to be filled to 80% of capacity. In practice, EBMUD maintains its reservoirs at an operating level between approximately 70% and 100% of capacity. The District's SCADA (System Control and Data Acquisition System), OP/NET, automatically starts pumping units remotely from the Oakland Control Center to maintain reservoirs within this operating range.¹ Changes in reservoir levels during a single structure fire will only marginally (within a few percent) change the available fire flow rates.

All hydraulic analyses assume that fire flows are provided through available reservoir storage (unless otherwise noted). This provides a reliable source of water. The alternative to provide fire water flows through pumping was not explored in detail. Fire flows from pumped sources are less reliable, as there is probability that a pumping plant will fail to operate during a major fire, due to the loss of off-site PG&E electric power.

¹Communication, J. Jacobs and M. Falarski (EBMUD) to K. Goettel (VSP), December 9, 1992.

Table 4-2
Friction Coefficients

Pipe Type	Lining	Age	2 Inch	4 Inch	6 Inch	8 Inch	10 Inch	12 Inch
Cast Iron	Unlined	Pre 1919	35	40	55			
		Pre 1929	35	50	60			
		Pre 1939	40	55	65	75	90	90
Cast Iron	Lined			105	110	105	120	120
Steel	Unlined	All			65			80
Steel	Lined	All			130	130	130	130
Asb. Cmt.		All		130	130			

Such power losses did occur during the October 1991 firestorm.

In most areas of the District, the ratio of fire flow demands to average daily demands is large. Therefore, pipe sizes are controlled mostly upon providing the required fire flows. In this case, other parameters which sometimes are considered in optimizing pipe diameter selection do not control: such as the cost to install various diameter pipes, or the cost of energy to pump at higher pressures.

For hydrants not able to provide the fire flow levels, pipe replacements (or other upgrades) were tested in the hydraulic models. The upgrades were considered satisfactory if the residual pressure was at least 20 psi (in some cases, the as-is or upgraded pipe network had marginal residual pressures between 10 psi and 20 psi, and these cases are specifically noted in the text).

The maximum water velocities in the network under fire flow conditions were not optimized. There is a trade-off between higher velocities, higher friction in the pipes, and possible surge forces. A high velocities (above 5 to 10 feet per second), friction losses become high: if these conditions existed under normal usage, there would likely be an excessive pumping cost to maintain these flows.

Surge forces can also lead to undue stress on the pipe. Surge forces can be kept small if velocities are kept below about 5 feet per second. At fire flows of 1,500 gpm through a single 6 or 8 inch pipe, velocities are about 17 or 10 feet per second, respectively. In a looped 6 inch pipe system, where two 6 inch pipes deliver the flow the fire flow to a single hydrant, the velocity in one of the two 6 inch feeds is about 11 to 12 feet per second.

In the hydraulic analyses of the as-built and the upgraded systems described in this report, the pipe upgrades were selected to maintain the minimum residual pressures, and not to minimize velocities. The additional cost to re-fit each pressure zone to limit velocities to about 10 feet per second would require substantial additional replacement of 6 inch pipe with 8 inch pipe. The additional cost to re-fit each pressure zone to limit velocities to about 5 feet per second would require substantial additional replacement of 6 inch and 8 inch pipe with 12 inch pipe or looped 8 inch grids. Such upgrades to reduce velocities during times of fire suppression are probably not necessary.

During the October 1991 firestorm, the pipe network in the firestorm area was subjected to multiple hydrant flows in the 1,000 to 1,500 gpm range. According to District staff, no pipe breaks occurred (newspaper reports of water runoff attributed to pipe breaks were actually accounted for by the large number of exposed service taps after dwellings were destroyed). This track record suggests that the possible surges or high velocities actually experienced during the firestorm did not cause pipe breaks. Therefore, it is probably not necessary to limit velocities to a low level, such as 5 feet per second. However, this issue should be verified before embarking on the actual pipe upgrade installations in the firestorm area.

The following nine sub-sections contain detailed hydraulic analyses of fire flow rates from each of the 267 hydrants in the modeled area. For each hydrant, current

performance is analyzed. If the hydrant is below the 1,500 or 1,000 gpm fire flow levels, then specific pipe replacements necessary to bring the hydrant up to the stated level are summarized. These technical sub-sections report detailed hydraulic analyses, which are necessary to evaluate possible system upgrades, but may not be of interest to the general reader.

TECHNICAL SUB-SECTIONS

4.1.1 A13B Berkeley Hills

The Berkeley Hills pressure zone (A13B) was created in 1973 to serve as an emergency zone to fight fires in the local area. The zone is composed of 12 inch diameter pipe along Grizzly Peak Boulevard, stretching from the pumping plant to the reservoir. There is only one residential service in this zone.

A13B has 0.9 miles of pipe. A13B's single reservoir is the Berkeley Hills reservoir (redwood tank, 396,000 gallon capacity). A13B's single pumping plant is the Berkeley Hills pumping plant (2 pumps, each 0.4 mgd, total 0.8 mgd, or 550 gpm). There are 6 hydrants in the zone. The entire zone is modeled.

There are six hydrants in the zone. Table 4-3 summarizes the fire flows at each hydrant. In this table, and similar tables for the other pressure zones modeled in this chapter, "as-built" refers to the current fire flow performance of the existing water distribution system. Results for the as-built pressure zone are as follows:

- 6 out of 6 hydrants provide a 1,500 gpm fire flow at a minimum residual pressure of 20 psi.

No hardware upgrades are needed to bring this pressure zone up to the required 1,500 gpm fire flow level. However, as discussed in Section 2.6, a candidate upgrade would be to inter-tie the A13B Berkeley Hills pressure zone with the B13Aa Hilltop and B13A Skyline pressure zones. This inter-tie would improve fire flow durations.

4.1.2 A11A Gwin

The Gwin pressure zone (A11A) was fully involved in the October 20, 1991 firestorm. There are (as of 1990) 139 services in the zone.

A11A has 1.8 miles of pipe. A11A's single reservoir is the Gwin reservoir (steel tank, 496,000 gallon capacity). A11A's single pumping plant is the Gwin pumping plant (3 pumps, two at 0.3 mgd, one at 0.5 mgd, total 1.1 mgd, or 750 gpm). There are 16 hydrants in the zone. The Bristol regulator (flow capacity approximately 1,500 gpm), located at hydrant 6816 (southern-most end of the zone), can be used to supply the A9B Strathmoor pressure zone from the A11A Gwin pressure zone. The entire zone is modeled.

Table 4-3
A13B Berkeley Hills Pressure Zone - Hydrant Flows (As Built)

HYDRANT	AS BUILT FIRE FLOW
10671	1500 gpm
10670	1500 gpm
10669	1500 gpm
10668	1500 gpm
10667	1500 gpm
10249	1500 gpm

Table 4-4
A11A Gwin Pressure Zone - Minimum Hydrant Flows
(As Built and After Upgrade to 1,500 gpm)

HYDRANT	AS BUILT FIRE FLOW	FIRE FLOW AFTER UPGRADES
6816	1500 gpm	
3274	1500 gpm	
3276	1500 gpm	
10980	1500 gpm	
11180	1500 gpm	
15434	1500 gpm	
4320	1500 gpm	
3276	1500 gpm	
11181	1500 gpm	
5295	1500 gpm	
12174	1500 gpm	
10248	1500 gpm	
14170	1500 gpm	
15125	1500 gpm	
12630	1200 gpm	1500 gpm (upgrades 1, 2a)
12631	1500 gpm	

There are 16 hydrants in the zone. Table 4-4 summarizes the fire flows at each hydrant. Results are as follows:

- 15 out of 16 hydrants meet the 1,500 gpm fire flow at a minimum residual pressure of 20 psi.
- 1 hydrant (12630, western-most edge of the zone) does not meet the 1,500 gpm fire flow. This hydrant would meet the fire flow with the Gwin pumps turned on.
- If the Gwin pumps are not turned on, then two alternative pipe replacements were considered in order to improve the fire flow at hydrant 12630:

1. (Tables 4-12 and 4-13 refer to this upgrade as upgrade 1). Replace 502² feet of 6SMM59³ inch pipe with 8 inch pipe⁴, on Chancellor⁵, from hydrant 12630 eastwards. This improves fire flows to 1,500 gpm at a marginal residual pressure (9 psi).

²Pipe lengths are based on digitized map information. Actual lengths of pipe in the field may vary by several percent.

³Note: existing pipe nomenclature reflects that in use by the District on "B" maps. The first digit ("6" in this case) is the diameter of the pipe. The first letter ("S" in this case) is the pipe material (S = steel, C = cast iron, A = asbestos cement). The next letters, if any, describe the lining and coating of the pipe - if no letters are present, then the pipe is unlined and uncoated. The last digits ("59" in this case) is the year the pipe was placed in service (1959 in this case).

⁴New and replacement pipe are assumed to have friction coefficients of 130. An alternative would be to clean existing pipe (if no pipe diameter increase is otherwise warranted). District studies are now being performed for 4 and 6 inch diameter pipe in the Panoramic pressure zone, to study the effectiveness and costs associated with such pipe cleaning. It is generally believed that pipe cleaning will improve friction coefficients from about 50 to 70 for 4 inch diameter pipe; and perhaps a similar type of improvement for 6 inch diameter pipe. In most cases, the pipe upgrades described in this report will result in friction coefficient increases from the 50 to 60 range, up to 130 (new lined pipe). Therefore, the pipe cleaning alternative would require longer lengths of pipe to be cleaned, as compared to lengths of pipe to be replaced; in some areas, this may not be practical. The pipe cleaning alternative may deserve further study, especially due to its potential economies as compared to pipe replacement.

⁵Refer to District B maps for locations of hydrants, streets, and pipe information.

2a. (Upgrade 2a) Include upgrade 1, plus replace 469 feet of 6C35 pipe with 8 inch pipe, on Norfolk, from the intersections of Strathmoor to Marlborough Terrace. This improves fire flows to 1,500 gpm at a residual pressure of 18 psi.

2b. Include upgrade 1, plus replace 569 feet of 8C26 pipe with 8 inch pipe, on Strathmoor, from the intersections of Drury Road to Kenilworth Road. This improves fire flows to 1,500 gpm at a residual pressure of 19 psi.

4.1.3 A9B Strathmoor

The Strathmoor pressure zone (A9B) was fully involved in the October 20, 1991 firestorm. There are (as of 1991, pre-fire) approximately 465 services in the zone.

A9B has 5.5 miles of pipe. Of this total, about 1 mile reflects planned pipe improvements, for new residential development in the Hiller Highlands area, and the linking together of the former A9Aa regulated zone into the A9B Strathmoor zone. A9B's single reservoir is the Strathmoor reservoir (concrete tank, 497,000 gallon capacity). A9B's single pumping plant is the Strathmoor pumping plant (3 pumps, each at 0.3 mgd, total 1.2 mgd, or 825 gpm). Two pressure regulators can also feed the zone: the Bristol regulator, from the A11A Gwin pressure zone; and the Caldecott regulator (capacity approximately 1,200 gpm), from the B11A Pinehaven pressure zone. Normal service is this zone is from the Strathmoor reservoir; the regulators can supply additional water in the event of unusually high demand.

The District⁶ has recently reset the settings at the Bristol and Caldecott regulators. The new settings are 44 psi (Bristol) and 34 psi (Caldecott). These new settings are reflected in the model.

There are 42 hydrants in the zone. Table 4-5 summarizes the fire flows at each hydrant. Results are as follows:

- 40 out of 42 hydrants meet the 1,500 gpm fire flow at a minimum residual pressure of 20 psi.
- 1 hydrant (15170) can only provide 450 gpm. This hydrant is located at the corner of Buckingham and Norfolk. Within 100 feet of this location is hydrant 3274, located in the A11A Gwin pressure zone. Hydrant 3274 can provide a fire flow of 1,500 gpm. Therefore, it is technically unnecessary to upgrade the water system to also provide 1,500 gpm from hydrant 15170. However, a study was performed to determine what the minimum upgrades would be in order to provide higher fire flows from hydrant 15170. The following alternatives were studied:

⁶Conversation, B. McGowan (EBMUD) to J. Eiding (G&E), October 15, 1992.

Table 4-5
A9B Strathmoor Pressure Zone - Hydrant Flows
(As Built and After Upgrade to 1,500 gpm)

HYDRANT	AS BUILT FIRE FLOW	FIRE FLOW AFTER UPGRADES
12110	1500 gpm	
15169	1500 gpm	
11179	1500 gpm	
2688	1500 gpm	
10368	1500 gpm	
2689	1500 gpm	
16164	1500 gpm	
15168	1500 gpm	
14047	1500 gpm	
14046	1500 gpm	
10192	1500 gpm	
10191	1500 gpm	
10193	1500 gpm	
14048	1500 gpm	
15198	1500 gpm	
15199	1500 gpm	
12002	1500 gpm	
12001	1500 gpm	
10710	1500 gpm	
12103	1500 gpm	
12102	1500 gpm	
14049	1500 gpm	
14050	1500 gpm	
5229	1500 gpm	
18318	1500 gpm	
10317	1500 gpm	
4469	1500 gpm	
15170	450 gpm	Flow OK with adjacent hydrant; or 1200 gpm with upgrade 3; or 1500 gpm with upgrade 4
14116	1500 gpm	
14115	1500 gpm	
3075	1500 gpm	
1921	1500 gpm	
14003	1500 gpm	
14000	1500 gpm	
14001	1500 gpm	
14002	1500 gpm	
14173	1500 gpm	
14099	1500 gpm	
14098	1500 gpm	
14097	1400 gpm	1500 gpm at 10 psi residual.
15225	1500 gpm	
15224	1500 gpm	

3. Replace 791 feet of 6C28 pipe with an 8 inch pipe, on Buckingham, from the intersections of Norfolk Rd. and Bristol Dr. This improves the fire flows at hydrant 15170 to 1,200 gpm.

4. A 1,500 gpm fire flow at hydrant 15170 is limited by small pipe sizes in the B11A Pinehaven pressure zone feeding the Caldecott regulator. Upgrade 3, plus additional upgrades of the 6C47 pipe on Skyline Blvd. in B11A (upgrade 20, described in Section 4.1.7) will improve fire flows to 1,500 gpm at hydrant 15170.

- 1 hydrant (14097) meets the 1,500 gpm fire flow at marginal residual pressure (11 psi). This hydrant is located at the dead end (and highest elevation) of Bay Forest Dr. Upgrades to provide the somewhat higher pressure needed to meet 20 psi would involve replacement of new 6 inch AC pipe with 8 inch pipe; this alternative is probably not economically justified.

4.1.4 A7B Amito

About 90% of the Amito pressure zone (A7B) was involved in the October 20, 1991 firestorm. The remaining 10%, located near the northern edge of the zone, along and near Claremont avenue, was not in the fire. There are (as of 1991, pre-fire) approximately 365 services in the zone. One of these services was the Parkwood Apartment complex, serving about 400 apartment units, which used about 30% of the normal water demand for the zone.

A7B has 6.5 miles of pipe. A7B has two reservoirs: the Amito reservoir (concrete tank, 493,000 gallons capacity) and the Sherwick reservoir (steel tank, 400,000 gallons capacity). The Amito tank was damaged in the October 20, 1991 firestorm. A replacement Amito tank is now being designed and will have a capacity of about 650,000 gallons. A7B's single pumping plant is the Amito pumping plant (2 pumps, each at 0.9 mgd, total 1.8 mgd, or 1,250 gpm).

There are 51 hydrants in the zone. Table 4-6 summarizes the fire flows at each hydrant. Results are as follows:

- 38 of 51 hydrants meet the 1,500 gpm fire flow at a minimum residual pressure of 20 psi. 1 of 51 hydrants meet the 1,500 gpm fire flow at marginal residual pressure. 14 of 51 hydrants do not meet the 1,500 gpm fire flow.
- Hydrant 16163 has a flow of only 750 gpm. However, this hydrant is located about 100 feet west of hydrant 16164, located in the A9B Strathmoor pressure zone. As hydrant 16164 can provide a 1,500 gpm fire flow, it is technically unnecessary to upgrade hydrant 16163 to 1,500 gpm.
- Hydrant 4931 has a flow of only 1,100 gpm. Both hydrants 4931 and 16163 are located on a 6CM50 pipe, which is adjacent to the zone gate to A9B Strathmoor pressure zone, along Grand View Dr. One alternative (upgrade 5) would be to

Table 4-6 (Part 1)
A7B Amito Pressure Zone - Hydrant Flows
(As Built and After Upgrade to 1,500 gpm)

HYDRANT	AS BUILT FIRE FLOW	FIRE FLOW AFTER UPGRADE
10525	1500 gpm	
11933	1500 gpm	
11932	1500 gpm	
11923	1500 gpm	
11922	1500 gpm	
11061	1500 gpm	
3511	1500 gpm	
17795	1500 gpm	
3090	1500 gpm	
11747	1500 gpm	
10709	1500 gpm	
10708	1500 gpm	
12609	1500 gpm	
12610	1500 gpm	
12611	1500 gpm	
12612	1500 gpm	
12608	1500 gpm	
4931	— 1100 gpm	1500 gpm with upgrade 5 (Rezone); or 1500 gpm with upgrade 6
16163	— 750 gpm	Flow OK with adjacent hydrant; or 1500 gpm with upgrade 5 (rezone); or 1050 gpm with upgrade 6
4418	1500 gpm	
10338	1500 gpm	
5228	1500 gpm	
10557	1500 gpm	
10555	1500 gpm	
10556	1500 gpm	
15383	1500 gpm	
5039	1500 gpm	
4465	1500 gpm	
19399	1500 gpm	
4466	1500 gpm	
13933	1500 gpm	
5225	1500 gpm	
4032	1500 gpm	
3525	— 1400 gpm	1500 gpm with upgrades 7, 8, 9, 10
5226	— 1250 gpm	1500 gpm with upgrades 7, 8, 9, 10
15384	— 1100 gpm	1500 gpm with upgrades 7, 8, 9, 10
5283	— 950 gpm	1500 gpm with upgrades 7, 8, 9, 10
4467	— 850 gpm	1500 gpm with upgrades 7, 8, 9, 10
4468	— 1350 gpm	1500 gpm with upgrades 7, 8, 9, 10
10263	1500 gpm	
15240	1500 gpm	

Table 4-6 (Part 2)
A7B Amito Pressure Zone - Hydrant Flows
(As Built and After Upgrade to 1,500 gpm)

HYDRANT	AS BUILT FIRE FLOW	FIRE FLOW AFTER UPGRADE
5227	1500 gpm	
12236	1500 gpm	
19112	1500 gpm	
15382	1250 gpm	1500 gpm with upgrades 11, 12, 13, 14, 15
16218	1150 gpm	1500 gpm with upgrades 11, 12, 13, 14, 15
3080	1150 gpm	1500 gpm with upgrades 11, 12, 13, 14, 15
18122	900 gpm	1500 gpm with upgrades 11, 12, 13, 14, 15
18123	850 gpm	1500 gpm with upgrades 11, 12, 13, 14, 15
13320	850 gpm	1500 gpm with upgrades 11, 12, 13, 14, 15
11422	700 gpm	1500 gpm with upgrades 11, 12, 13, 14, 15

simply move the zone gate on Grand View Dr. from its current location, westward about 300 feet. This would put both hydrants 4931 and 16163 into the A9B pressure zone. The static pressure at these hydrants would increase from 36 psi to 126 psi. The static pressure on Dorothy Place (currently in A7B, but would be re-zoned into A9B) would increase to 145 psi. The District tries to maintain static pressures below 120 psi.⁷ This type of re-zoning is possible, but the District would need to ensure that suitable pressure regulators are provided to each house served in the re-zoned area.

- An alternative to upgrade 5, to increase fire flows at hydrant 4931 is as follows:

6. Replace 285 feet of 6CM50 pipe with an 8 inch pipe, on Grand View Dr., beginning at hydrant 4931, in a south and then west direction, until the intersection with the 12SMM66 pipe. Do not re-zone the 4931 or 16163 hydrants. This alternative increases the fire flow to 1,500 gpm at hydrant 4931, and 1,050 gpm at hydrant 16163.

- Hydrants 3525, 5226, 15384, 5283, 4467, and 4468 will all meet a fire flow of 1,500 gpm by installing the following upgrades:

7. Replace 1,144 feet of 6SMM61 pipe with an 8 inch pipe, on Gravatt Dr., from the intersection with the 12SMM pipe below the Amato tank, to the intersection of Stephens Way.

8. Replace 344 feet of 6C27 pipe with an 8 inch pipe, on Stephen Way between the two intersections with Gravatt Dr.

9. Replace 445 feet of 6C27 pipe with an 8 inch pipe, on Gravatt Dr., from 200 to 245 Gravatt Dr.

10. Replace 554 feet of 6C27 pipe with a 6 inch pipe, on Alvarado Rd., from the intersection of Alvarado Rd. and Siler Pl. west to hydrant 4468 on Alvarado Rd.

- Hydrants 15382, 16218, 3080, 18122, 18123, 13320 and 11422 will all provide a fire flow of 1,500 gpm by installing the following upgrades:

11. Replace 314 feet of 6C26 pipe with an 8 inch pipe, on the 10 foot path between Siler Pl and Rispin Dr.

12. Replace 207 feet of 6SMM58 pipe with an 8 inch pipe, on Rispin Dr., from the 10 foot path to Claremont Ave.

13. Replace 883 feet of 6SMM58 pipe with an 8 inch pipe, on Claremont

⁷Conversation, B. Bode (EBMUD) to J. Eidinger (G&E), 10/19/92.

Ave., from Rispin Dr. to Alvarado Ave.

14. Replace 422 feet of 6SMM58 pipe with an 8 inch pipe, on Alvarado Ave., from Claremont Ave. to Gypsy Ln.

15. Replace 308 feet of 6SMM58 pipe with an 8 inch pipe, on Gypsy Ln., from Alvarado Ave. to the end of Gypsy Ln.

4.1.5 A5A Summit

The Summit pressure zone (A5A) was partially involved in the October 20, 1991 firestorm. The Summit zone stretches from the Tunnel Road area, just below Hiller Highlands area, to well north of the U.C. Berkeley campus. Most of the zone, in fact, is located North of the Berkeley campus. In the area of the firestorm, there are (as of 1991, pre-fire) 246 services.

A5A has 27.4 miles of pipe (total), of which 1.8 miles is located within the firestorm area. The A5A hydraulic model includes 6.8 miles of pipe.

A5A has three reservoirs: Summit North, Summit, and Summit South. These three reservoirs do not float together: the reservoirs are so far apart, that the hydraulic line losses connecting the system are such that one reservoir may be filling, while the other is emptying. For example, the OP/NET data showed that the Summit South reservoir was emptying, during the fire, even while the much larger Summit reservoir was filling. For modeling purposes, only the Summit South reservoir (concrete tank, 1,505,000 gallons capacity) is included.

A5A has four pumping plants: Summit North, Summit West, Summit East and Summit South. The Summit North and Summit West pumping plants are located too far away from the firestorm area to be effective. The Summit East pumping plant (2 pumps, one at 2.3 mgd, one at 2.6 mgd, total 4.9 mgd, or 3,400 gpm) and the Summit South pumping plant (3 pumps, one at 3.1 mgd, one at 3.2 mgd, one at 3.9 mgd, total 10.2 mgd, or 7,100 gpm) are effective in providing fire flows to the firestorm area, and are included in the hydraulic model. (The District has the flexibility of valving the Summit South #3 pump to provide flow into the B5A Dingee zone; normally, however, Summit #3 pumps to the Summit South Reservoir).

There are 27 hydrants in the A5A zone located in and near the firestorm area. Table 4-7 summarizes the fire flows at each hydrant. Results are as follows:

- 27 of 27 hydrants provide a 1,500 gpm fire flow rate at a minimum residual pressure of 20 psi.

Table 4-7
A5A Summit Pressure Zone - Hydrant Flows (As Built)

HYDRANT	AS BUILT FIRE FLOW
17143	1500 gpm
14957	1500 gpm
15988	1500 gpm
3801	1500 gpm
3791	1500 gpm
15385	1500 gpm
13417	1500 gpm
1743	1500 gpm
962	1500 gpm
361	1500 gpm
19744	1500 gpm
19743	1500 gpm
10236	1500 gpm
227	1500 gpm
12303	1500 gpm
260	1500 gpm
17793	1500 gpm
14769	1500 gpm
10177	1500 gpm
10164	1500 gpm
10562	1500 gpm
1348	1500 gpm
1449	1500 gpm
15248	1500 gpm
19742	1500 gpm
2784	1500 gpm
11746	1500 gpm

4.1.6 B13Aa Hilltop

The Hilltop pressure zone (B13Aa) was partially involved in the October 20, 1991 firestorm. The Hilltop zone stretches along Grizzly Peak Boulevard, above the firestorm area. There are (as of 1991, pre-fire) 33 services in this zone.

B13Aa has 1.0 miles of pipe. About one third of this total is a planned extension the zone northwards along Grizzly Peak Boulevard, to a new subdivision: Grizzly Peak Estates. This extension will be 12 inch diameter steel pipe. The hydraulic model covers the entire zone.

B13Aa has one reservoir: Hilltop. The Hilltop reservoir (redwood tank, 253,000 gallons capacity) was built in 1973, and replaced a smaller tank at the same location. At present time, the tank has enough water storage to supply a 1,500 gpm fire flow for 2 hours, with concurrent normal demands.

If the B13Aa pressure zone area is built out to include several hundred houses, then reservoir capacity may be limited in meeting fire flows plus normal concurrent demands. At the Hilltop site, there is no additional space to practically build a significantly larger tank; however, this B13Aa zone could be cross connected to the adjacent A13B and/or B13A zones to provide this additional reservoir capacity. The upgrades needed for these inter-ties are described in Section 5. B13Aa's single pumping plant is the Hilltop pumping plant (2 pumps, one at 0.3 mgd, one at 0.2 mgd, total 0.5 mgd, or 350 gpm).

There are 9 hydrants in the B13Aa zone. Table 4-8 summarizes the fire flows at each hydrant. Results are as follows:

- 2 of 9 hydrants provide a 1,500 gpm fire flow rate at a minimum residual pressure of 20 psi.
- Hydrant 5230 will provide a fire flow of 1,500 gpm by installing the following upgrades:
 - 16. Replace 539 feet of 6C38 pipe with a 6 inch pipe, on Skyline Blvd., from the intersection with a 8SMMB73 pipe below the Pinehaven Tanks, to 6321 Skyline Blvd.
- Hydrants 14857, 14858, 14856, 14859, 14860 and 19013 will all provide a fire flow of 1,500 gpm by installing the following upgrades:
 - 17. Replace 197 feet of 6CM46 pipe with an 8 inch pipe, from the Hilltop tank to Grizzly Peak Blvd.
 - 18. Replace 81 feet of 6CM46 pipe with an 8 inch pipe, on Grizzly Peak Blvd., west of the feed from the Hilltop tank.

Table 4-8
B13Aa Hilltop Pressure Zone - Hydrant Flows
(As Built and After Upgrade to 1,500 gpm)

HYDRANT	AS BUILT FIRE FLOW	FIRE FLOW AFTER UPGRADE
14857	1050 gpm	1500 gpm with upgrades 17 and 18
14858	1050 gpm	1500 gpm with upgrades 17 and 18
14856	1100 gpm	1500 gpm with upgrades 17 and 18
14859	1100 gpm	1500 gpm with upgrades 17 and 18
14860	1150 gpm	1500 gpm with upgrades 17 and 18
19013	1250 gpm	1500 gpm with upgrades 17 and 18
4550	1500 gpm	
10292	1500 gpm	
5230	950 gpm	1500 gpm with upgrade 16

Table 4-9
B11A Pinehaven Pressure Zone - Hydrant Flows
(As Built and After Upgrade to 1,500 gpm)

HYDRANT	AS BUILT FIRE FLOW	FIRE FLOW AFTER UPGRADE
15296	1500 gpm	
4321	900 gpm	1500 gpm with upgrades 19 and 20
10155	700 gpm	1500 gpm with upgrades 19 and 20
10812	800 gpm	1500 gpm with upgrades 19 and 20
3582	1500 gpm	
18390	1500 gpm	
15533	1500 gpm	
15921	1500 gpm	
4056	1500 gpm	
10240	1100 gpm	
4062	1500 gpm	1500 gpm with upgrade 21
19179	1500 gpm	
12155	1500 gpm	
121XX	1500 gpm	
3578	1500 gpm	

4.1.7 B11A Pinehaven

The Pinehaven pressure zone (B11A) was partially involved in the October 20, 1991 firestorm. The Pinehaven zone extends down from Skyline Boulevard, above the firestorm area, along Broadway Terrace. There are (as of 1991, pre-fire) 173 services in this zone.

B11A has 2.1 miles of pipe. One short piece of 6 inch plastic pipe is planned to be added to the zone, to add hydrant H19179. The hydraulic model includes the entire zone.

B11A has two reservoirs: Pinehaven No. 1, and Pinehaven No. 2, both located at the same site. The Pinehaven No. 1 reservoir (steel tank, 207,000 gallons capacity) was installed at this location in 1939. The Pinehaven No. 2 reservoir (steel tank, 500,000 gallons capacity) was installed in 1988. The combined capacity of the two Pinehaven tanks is adequate for meeting normal consumption, plus a two hour fire flow at 1,500 gpm in the B11A zone. In addition, the A9B zone can draw water from the Pinehaven tanks through the Caldecott Regulator, located on Skyline Boulevard. B11A's single pumping plant is the Pinehaven pumping plant (2 pumps, each at 0.3 mgd, total 0.6 mgd, or 410 gpm).

There are 15 hydrants in the B13Aa zone. Table 4-9 summarizes the fire flows at each hydrant. Results are as follows:

- 11 of 15 hydrants provide a 1,500 gpm fire flow rate at a minimum residual pressure of 20 psi.
- Hydrants 4321, 10155 and 10812 will all provide a fire flow of 1,500 gpm by installing the following upgrades:

19. Replace 270 feet of 6C47 pipe with an 8 inch pipe, on Skyline Blvd., from the intersection of Broadway Terrace to 6049 Skyline Blvd.

20. Replace 640 feet of 6C47 pipe with an 8 inch pipe, on Skyline Blvd., from 6049 Skyline Blvd. to 5885 Skyline Blvd.

By installing upgrades 19 and 20, the feed from the B11A pressure zone to the A9B pressure zone, through the Caldecott Regulator, will also be improved, allowing increased fire flows in the A9B zone.

- Hydrant 10240 will provide a fire flow of 1,500 gpm by installing the following upgrade:

21. Replace 120 feet of 4CM49 pipe with a 6 inch pipe, on Farallon Way, from 6548 Farallon Way to 6575 Farallon Way.

4.1.8 B9A Thornhill

The Thornhill pressure zone (B9A) was partially involved in the October 20, 1991 firestorm.

The northern portion of the B9A pressure zone is completely modeled. The southern portion (Forestland) is located outside the firestorm area and is not modeled; it was split off from the Thornhill portion due to a landslide in 1982, breaking a 12 inch steel pipe on Armour Drive, and is now hydraulically unconnected. The landslide location is just south and west of hydrant H4767, extending for about 250 feet. The City of Oakland has apparently decided not to stabilize this landslide zone (at least not in the past 10 years). Except as otherwise noted in this report, all references to the Thornhill pressure zone, or B9A, refer only to the northern portion of the zone.

The western edge of the Thornhill pressure zone lies along Broadway Terrace, and Virgo. There were (as of 1991, pre-fire) 956 services in the total B9A zone, about half of which are in the northern Thornhill portion. The northern portion has 5.8 miles of pipe. The hydraulic model includes the entire northern portion of the zone.

B9A has one reservoir: Thornhill. The Thornhill reservoir (riveted steel tank, 193,000 gallons capacity) was installed in 1934. It is one of the two oldest steel reservoirs in the EBMUD system. It is an unanchored tank. Without modification, it is expected to fail (lose all water contents) in moderate, or large Hayward fault earthquake events.

The B9A zone is not served by a pumping plant. It's supply of water comes from the higher B11B Carisbrook pressure zone, through the Thornhill temporary regulator, located on Thornhill Drive, near Aspinwall Road. This 6 inch regulator was installed in 1982, as a means to supply water into the northern portion of the B9A zone, which was isolated from its pumping plant due to the 1982 landslide on Armour Drive. This method of supplying water into the B9A zone is inefficient, as the water has to be pumped up to the B11B Carisbrook pressure zone, then dropped 200 feet down to the Thornhill zone.

The Thornhill tank can provide a fire flow of 1,500 gpm for 2 hours, if the tank is full at the onset of the fire, and if there is no other consumption. Thus, fire flows, normal consumption, and emergency reserves, cannot be met solely by the storage capacity in the Thornhill tank.

A hydraulic model of part the B11B Carisbrook pressure zone was developed, in order to study the amount of water that can be supplied to the Thornhill regulator. The current "as-built" Carisbrook pressure zone can supply 750 gpm to the Thornhill regulator.

The District is currently planning to relocate and re-build the Thornhill regulator. The current location of the regulator is above ground, in a wood box. A replacement regulator should be capable of providing the full fire flow into the B9A pressure zone. In order to supply such flows, pipe replacements must be performed in the B11B Carisbrook pressure zone.

There are 38 hydrants in the B9A zone. Table 4-10 summarizes the fire flows at each hydrant. Results are as follows:

- 12 of 38 hydrants provide a 1,500 gpm fire flow rate at a minimum residual pressure of 20 psi. These 12 hydrants are all located near the Thornhill reservoir, along or nearby the 12 inch steel main.
- 1 of 38 hydrants, 12156, has marginal residual pressure at 1,500 gpm.
- 25 of 38 hydrants do not provide a 1,500 gpm fire flow rate.
- Hydrant 3797, 3798, 2055, 11443, 18XXX⁸, and 12156 will provide a fire flow of 1,500 gpm by installing the following B11B upgrade:

22. Replace 1,420 feet of 6C26 and 6C25 pipe to a 6 inch pipe, beginning at the Thornhill regulator, up the 5 foot path to Thornhill Dr., east along Thornhill Dr. until the intersection with Snake Rd. (Note: an upgrade to a new 6 inch pipe will provide the needed fire flows into the B9A zone; however, an upgrade to an 8 inch pipe will allow simultaneous fire flows in both the B9A and B11B zones).

- Hydrants 2636, 17378 and 4767 will provide a fire flow of 1,500 gpm by installing the following upgrade:

23. Reconnect these three hydrants from the 6C26 pipe on Armour Dr. to the 12SMM56 pipe on Armour Dr. This 12SMM56 pipe used to be the feed pipe to the northern part of the B9A zone, prior to the landslide on Armour Drive. By reconnecting these three hydrants to the larger 12 inch pipe, the larger pipe may need to be cleaned, as it may now have been out of service for 10± years. A gate valve and reaction block may also need to be installed in this pipe, just south of hydrant 4767.

- Hydrants 15673, 11719, 14717, 11720 and 15410 will provide a fire flow of 1,500 gpm by installing the following upgrades:

24. Replace 1,081 feet of 6CM39, 6CM46, 6A64 and 6A71 pipe with 10 inch pipe, on Sobrante Rd., from the intersection of Thornhill Dr. to east of Thorn Ct.

25. Replace 497 feet of 6A71 pipe with 8 inch pipe, on Sobrante Rd., from east of Thorn Ct. to the intersection of Oakwood Dr.

⁸Some hydrant numbers are illegible on District B maps. Digits which are illegible are denoted with an "X".

Table 4-10
B9A Thornhill Pressure Zone - Hydrant Flows
(As Built and After Upgrade to 1,500 gpm)

HYDRANT	AS BUILT FIRE FLOW	FIRE FLOW AFTER UPGRADE
14679	1500 gpm	
16935	1500 gpm	
11169	1500 gpm	
16936	1500 gpm	
4833	1500 gpm	
1648	1500 gpm	
15668	1500 gpm	
14122	1500 gpm	
15669	1500 gpm	
15670	1500 gpm	
15673	1300 gpm	1500 gpm with upgrades 24, 25; or 1500 gpm with upgrade 26
11719	1200 gpm	1500 gpm with upgrades 24, 25; or 1500 gpm with upgrade 26
14717	1000 gpm	1500 gpm with upgrades 24, 25; or 1500 gpm with upgrade 26
11720	800 gpm	1500 gpm with upgrades 24, 25; or 1500 gpm with upgrade 26
15410	550 gpm	1500 gpm with upgrades 24, 25; or 1500 gpm with upgrade 26
3476	1500 gpm	
3797	1000 gpm	1500 gpm with upgrade 22 (in B11B)
3798	900 gpm	1500 gpm with upgrade 22 (in B11B)
2055	600 gpm	1500 gpm with upgrade 22 (in B11B)
11443	600 gpm	1500 gpm with upgrade 22 (in B11B)
2636	600 gpm	1500 gpm with upgrade 23
17378	600 gpm	1500 gpm with upgrade 23
4767	600 gpm	1500 gpm with upgrade 23
18XXX	600 gpm	1500 gpm with upgrade 22 (in B11B)
12156	1450 gpm	1500 gpm with 10 psi residual
4854	1050 gpm	1500 gpm with upgrades 27, 28, 29, 30, 31, 32
2921	950 gpm	1500 gpm with upgrades 27, 28, 29, 30, 31, 32
10059	1050 gpm	1500 gpm with upgrades 27, 28, 29, 30, 31, 32
3584	650 gpm	1500 gpm with upgrades 27, 28, 29, 30, 31, 32
4272	1250 gpm	1500 gpm with upgrades 27, 28, 29, 30, 31, 32
5305	1250 gpm	1500 gpm with upgrades 27, 28, 29, 30, 31, 32
5310	1250 gpm	1500 gpm with upgrades 27, 28, 29, 30, 31, 32
17376	1250 gpm	1500 gpm with upgrades 27, 28, 29, 30, 31, 32
3652	1200 gpm	1500 gpm with upgrades 27, 28, 29, 30, 31, 32
3651	900 gpm	1500 gpm with upgrades 27, 28, 29, 30, 31, 32
17377	850 gpm	1500 gpm with upgrades 27, 28, 29, 30, 31, 32
3577	1250 gpm	1500 gpm with upgrades 27, 28, 29, 30, 31, 32
17793	1500 gpm	

26. An alternative to upgrading the long lengths of pipe on Sobrante Rd. would be to add about 400 feet of new 8 inch pipe on Oakwood Dr., connecting the B11B pressure zone to the B9A pressure zone at the intersection of Oakwood Dr. and Sobrante Rd. This alternative was not verified; however, the benefits of this upgrade would be to reduce the length of pipe upgrade from about 1,570 feet (upgrades 24 and 25 above) to 400 feet; and add a second zone gate between the B11B and B9A zones. Probably some length of the pipe on Sobrante Rd. would still need to be upgraded, especially near Thornhill Dr., in order to prevent extremely high static pressures; however, these high pressures could be resolved by installing a District-owned regulator along Sobrante Rd.; or individual house regulators. Another issue to be verified, before pursuing this option, is that there are some potentially unstable landslide zones along Oakwood Dr., which may merit geotechnical site investigations to confirm / mitigate such unstable landslide areas.

- Hydrants 4854, 2921, 10059, 3584, 4272, 5305, 5310, 17376, 3652, 3651, 17377 and 3577 will provide a fire flow of 1,500 gpm by installing the following upgrades:

27. Replace 873 feet of 6C22 pipe to 8 inch pipe, on Broadway Terrace, from the intersection of Pinehaven Rd. to Crown Ave.
28. Replace 65 feet of 6C38 pipe to 6 inch pipe, on Merriewood Dr., from Uranus Ave. to 6061 Merriewood Dr.
29. Replace 53 feet of 6C38 pipe to 6 inch pipe, on Merriewood Dr., at the intersection of Uranus Ave. and Crown Ave., through the street intersection.
30. Replace 306 feet of 6C38 pipe to 6 inch pipe, on Merriewood Dr., from the intersection of Crown Ave. to Robin Hood Way.
31. Replace 289 feet of 6C38 pipe to 6 inch pipe, on Crown Ave., from the intersection of Merriewood Dr. to 6250 Crown Ave.
32. Replace 250 feet of 4C22 pipe to 6 inch pipe, on a 10 foot path spanning from 11059 Broadway Terrace to 10055 Broadway Terrace.

Another alternative to improve fire flows in the B9A pressure zone would be to rebuild the 12 inch steel pipe from the Forestland reservoir to the northern B9A Thornhill pressure zone, along Armour Dr. This would involve about 250 feet of pipe. Concurrent costs would be the stabilization of the landslide on Armour Dr. This 12 inch pipe upgrade would alleviate the need to upgrade the 1,420 feet of pipe in the B11B Carisbrook pressure zone feed to the Thornhill Regulator; however, the B11B pressure zone needs some upgrades anyway to provide fire flows within that zone. This 12 inch pipe upgrade would also substantially increase fire flow durations throughout the B9A Thornhill pressure zone, as the Forestland reservoir has 3,400,000 gallon capacity. This 12 inch pipe upgrade would also eliminate the excess power costs needed to pump water up to the

B11B pressure zone, for ultimate consumption in the B9A pressure zone (and B11A pressure zone, which feeds off of B9A Thornhill pressure zone). This 12 inch pipe upgrade would also alleviate the need to build a new pumping plant to serve the B11A pressure zone from the B7A pressure zone (this new pumping plant is currently being considered by the District, in order to eliminate the excess power costs of pumping up to B11B, regulating down to B9A, and then pumping up to B11A).

4.1.9 B7A Joaquin Miller

The Joaquin Miller pressure zone (B7A) was partially involved in the October 20, 1991 firestorm. Most of the area involved was located near the Swainland reservoir, east of Highway 13. A smaller portion of the area involved was located west of Highway 13, on Cochrane Avenue and Sheridan Road.

B7A has 28.5 miles of pipe. The hydraulic model includes the northern portion of the zone, with 11.4 miles of pipe, and about 1,060 services. The model extends southwards as far as LaSalle Avenue.

B7A has three reservoirs: Swainland, Montclair and Joaquin Miller. The Swainland reservoir (concrete tank, 1,998,000 gallons capacity) was installed in 1964. The Montclair reservoir (concrete tank, 1,550,000 gallons capacity) was installed in 1937. The Joaquin Miller reservoir is located at the south end of the B7A zone, outside the modelled portion of the zone. The Joaquin Miller reservoir is hydraulically connected to the northern part of the zone through small diameter pipe, and does not have much influence for water flows in the firestorm area.

The B7A zone is served by two pumping plants: the Montclair pumping plant (3 pumps, two each at 3.4 mgd, one at 2.0 mgd, total 8.8 mgd, or 6,100 gpm) and the Joaquin Miller pumping plant (3 pumps, two each at 1.4 mgd, one at 1.5 mgd, total 4.3 mgd, or 3,000 gpm).

The reservoirs serving the northern end of the B7A zone (Swainland and Montclair) can each provide a fire flow rate of 1,500 gpm for a 2 hour duration.

There are 63 hydrants in the modeled portion of the B7A zone. Of these, 36 hydrants are located east of Highway 13 (see Table 4-11, part 1), and 27 hydrants are located west of highway 13 (see Table 4-11, part 2). Table 4-11 (parts 1 and 2) summarizes the fire flows at each hydrant. Results are as follows:

- East of Highway 13, 33 of 36 hydrants provide a 1,500 gpm fire flow rate at a minimum residual pressure of 20 psi.
- East of Highway 13, 3 of 36 hydrants do not provide a 1,500 gpm fire flow rate.
- West of Highway 13, 23 of 27 hydrants provide a 1,000 gpm fire flow rate at a minimum residual pressure of 20 psi.

Table 4-11 (Part 1)
Joaquin Miller Pressure Zone East of Highway 13 - Hydrant Flows
(As Built and After Upgrade to 1,500 gpm)

HYDRANT	AS BUILT FIRE FLOW	FIRE FLOW AFTER UPGRADE
95815	1500 gpm	
12068	1500 gpm	
14547	1500 gpm	
14546	1500 gpm	
12072	1500 gpm	
12252	1500 gpm	
13510	1500 gpm	
12070	1500 gpm	
12071	1500 gpm	
3019	1500 gpm	
10592	1500 gpm	
12508	1500 gpm	
3020	1500 gpm	
15389	1500 gpm	
4271	1500 gpm	
4273	1500 gpm	
10590	1500 gpm	
17045	1500 gpm	
3685	1300 gpm	1500 gpm with upgrade 33
3576	1500 gpm	
10589	1500 gpm	
3684	1500 gpm	
3682	1500 gpm	
3683	1500 gpm	
3678	1500 gpm	
12088	1500 gpm	
1968	1500 gpm	
3384	1500 gpm	
12832	1500 gpm	
1644	1500 gpm	
3382	1500 gpm	
5298	1500 gpm	
5297	450 gpm	1500 gpm with upgrades 34,35, 36 (15 psi residual); or 1500 gpm with upgrade 37 (re-zone)
5296	650 gpm	1500 gpm with upgrades 34, 35, 36; or 1500 gpm with upgrades 34, 35, 37
5315	1500 gpm	
7915	1500 gpm	

Table 4-11 (Part 2)
B7A Joaquin Miller Pressure Zone West of Highway 13 - Hydrant Flows
(As Built and After Upgrade to 1,500 gpm)

HYDRANT	AS BUILT FIRE FLOW	FIRE FLOW AFTER UPGRADE
12116	1000 gpm	
4790	1000 gpm	
2842	1000 gpm	
10704	1000 gpm	
2843	1000 gpm	
10410	1000 gpm	
18529	1000 gpm	
4539	1000 gpm	
13209	1000 gpm	
10566	1000 gpm	
2922	1000 gpm	
3430	1000 gpm	
15419	850 gpm	1000 gpm with upgrade 38
15879	800 gpm	1000 gpm with upgrade 38
3013	1000 gpm	
2552	1000 gpm	
3011	1000 gpm	
3010	1000 gpm	
16642	1000 gpm	
2553	1000 gpm	
16643	1000 gpm	
19977	1000 gpm	
19975	1000 gpm	
19066	1000 gpm	
11448	1000 gpm	
3251	850 gpm	1000 gpm with upgrade 39
3252	850 gpm	1000 gpm with upgrade 39

- West of Highway 13, 4 of 27 hydrants do not provide a 1,000 gpm fire flow rate.
- Hydrant 3685 (east of Highway 13) will provide a fire flow of 1,500 gpm by installing the following upgrade:

33. Replace 947 feet of 6C38 pipe to 6 inch pipe, on Capricorn Ave., from 268 Capricorn to the intersection of Broadway Terrace.

- Hydrants 5296 and 5297 (east of Highway 13) will provide a fire flow of 1,500 gpm by installing the following upgrades. Note that with these upgrades, the residual pressure at hydrant 5297 is 15 psi (marginal):

34. Replace 210 feet of 8C33 pipe to 8 inch pipe, on Merriewood Dr. and Thornhill Dr., beginning at 5516 Merriewood Dr. to the intersection of Doncaster Pl.

35. Replace 382 feet of 6C22 pipe to 8 inch pipe, on Thornhill Dr., from Doncaster Pl. to Beau Forest Dr.

36. Replace 1,132 feet of 6CM53 pipe to 8 inch pipe, on Beau Forest Dr., from the intersection of Thornhill Dr. to Valley View Rd.

- Alternatively, hydrant 5297 could be re-zoned (upgrade 37) into the B9A zone, at the intersection of Valley View Rd. Analyses were not performed for this alternative, but the lengthy amounts of pipe replaced on Beau Forest Dr. (1,132 feet) could be reduced.

- Hydrants 15419 and 15879 (west of Highway 13) will provide a fire flow of 1,000 gpm by installing the following upgrade:

38. Replace 489 feet of 6C24 pipe to 6 inch pipe, on Amy Dr., from Hilltop Cres. to Harbord Dr.

- Hydrants 3251 and 3252 (west of Highway 13) will provide a fire flow of 1,000 gpm by installing the following upgrade:

39. Replace 275 feet of 6C31 pipe to 6 inch pipe, on Florence Ave., from the intersection of Proctor Ave. to Cochrane Ave.

4.1.10 Summary of Upgrades to Improve Fire Flow Rates

Tables 4-12 and 4-13 provide summary statistics for the upgrades to improve fire flow rates in nine pressure zones analyzed in this report. The key results of the analyses are as follows:

- Six of the nine pressure zones have at least one hydrant that cannot provide fire flows equal to the recently proposed standards for new construction.

Table 4-12
Summary Statistics - Upgraded Pipe Lengths

Pressure Zone	Pipe Length in Total Zone (Miles)	Pipe Length in Hydraulic Model (Miles)	Total Hydrants in Hyd. Model	Do Not Meet Flow	6 Inch Pipe (Feet)	8 Inch Pipe (Feet)	10 Inch Pipe (Feet)	Upgrades
A13B Berkeley Hills	0.9	0.9	6	0	0	0	0	
A11A Gwin	1.8	1.8	16	1	0	971	0	1, 2a
A9B Strathmoor	5.5	5.5	42	2*	0	0	0	
A7B Amato	6.5	6.5	51	14**	554	4352	0	6-15
A5A Summit	27.4	6.8	27	0	0	0	0	
B13Aa Hilltop	1.0	1.0	9	7	539	278	0	16-18
B11A Pinehaven	2.1	2.1	15	4	120	910	0	19-21
B9A Thornhill***	10.7	5.8	38	25	2,383	1,370	1,081	22-25, 27-32
B7A Joaquin Miller	28.5	11.4	63	7	1,711	1,724	0	33-36, 38-39
TOTALS	84.4	41.8	267	59	5,307	9,605	1,081	

OK

*Buildout not recommended without necessary storage & flows
landslide isolated parts of P2, causing problems*

Notes:

- * At one hydrant location, a nearby hydrant in the next pressure zone provides combined fire flow over 1,500 gpm. At one hydrant location, 1,500 gpm can be met with marginal residual pressure.
- ** A nearby hydrant in the next pressure zone provides combined fire flow over 1,500 gpm at one hydrant individually not meeting fire flow.
- *** Feed into B9A Thornhill limited by pipes in B11B Carisbrook pressure zone. Pipe lengths include 1,420 feet of 6 inch pipe replacement in B11B.

Table 4-13
Summary of Upgrade Alternatives

UPGRADE DESCRIPTION	PRESSURE ZONE	NEW 6 IN. FEET	NEW 8 IN. FEET	NEW 10 IN. FEET	NOTES
1 Replace 6SMM59	A11A		502		Required
2a Replace 6C35	A11A		469		Optional, or use upgrade 2b
2b Replace 8C26	A11A		569		Optional alternative to 2a
3 Replace 6C28	A9B		791		Optional
4 Replace 6C47	A9B - B11A		640		Optional. Same as Upgrade 20
5 Rezone hydrants from A7B to A9B	A7B - A9B				Required; or use upgrade 6
6 Replace 6CM50	A7B		285		Alternate to 5
7 Replace 6SMM61	A7B		1144		Required
8 Replace 6C27	A7B		344		Required
9 Replace 6C27	A7B		445		Required
10 Replace 6C27	A7B	554			Required
11 Replace 6C26	A7B		314		Required
12 Replace 6SMM58	A7B		207		Required
13 Replace 6SMM58	A7B		883		Required
14 Replace 6SMM58	A7B		422		Required
15 Replace 6SMM58	A7B		308		Required
16 Replace 6C38	B13Aa	539			Required
17 Replace 6CM46	B13Aa		197		Required
18 Replace 6CM46	B13Aa		81		Required
19 Replace 6C47	B11A		270		Required
20 Replace 6C47	B11A		640		Required
21 Replace 4CM49	B11A	120			Required
22 Replace 6C25 and 6C26	B9A - B11B	1420			Required. Alternate is 12" through landslide zone
23 Reconnect hydrants from 6 to 12	B9A				Required
24 Replace 6CM39, 6CM46, 6A64,6A71	B9A			1081	Required; or use upgrade 26
25 Replace 6A71	B9A		497		Required; or use alternate 26
26 Rezone	B9A - B11B		400		Alternate to 24 + 25
27 Replace 6C22	B9A		873		Required
28 Replace 6C38	B9A	65			Required
29 Replace 6C38	B9A	53			Required
30 Replace 6C38	B9A	306			Required
31 Replace 6C38	B9A	289			Required
32 Replace 4C22	B9A	250			Required
33 Replace 6C38	B7A	947			Required
34 Replace 8C33	B7A		210		Required
35 Replace 6C22	B7A		382		Required
36 Replace 6CM53	B7A		1132		Required; or use upgrade 37
37 Rezone	B7A - B9A				Alternate
38 Replace 6C24	B7A	489			Required
39 Replace 6C31	B7A	275			Required

- On average, the nine pressure zones can deliver flows equal to the proposed standards for new construction to 77% of the hydrants. An additional 1% of the hydrants can provide such fire flows, at marginal residual pressures. 22% of the hydrants (59 hydrants) cannot provide such fire flows.

Various upgrade alternatives were analyzed. Upgrades which would bring all of the hydrant flows in these zones to the proposed standards for new construction were evaluated. Key results of this analysis in the firestorm area are as follows:

- Replacement of key sections of older smaller diameter pipe will result in providing higher fire flow rates for all hydrants. To bring all hydrants in these zone up the fire flow standard proposed for new construction, approximately 16,000 feet of pipe would have to be replaced with new 6, 8 or 12 inch pipe.
- To provide a 1,500 gpm fire flow from a single hydrant, all hydrants need to be installed with pumper outlets. Not all hydrants in the nine pressure zones currently have pumper outlets. In addition, some hydrants attached to 4 inch mains may use 4 inch laterals, which would also limit the fire flows below 1,500 gpm. Therefore, in addition to the pipe upgrades described in detail in this report, the District will also need to:
 - Install new hydrants at all locations without pumper outlets.
 - Replace 4 inch laterals with 6 inch laterals.

Specific locations where these hydrant replacements and lateral upgrades are needed were not tabulated as part of this project. However, only about two or three 4 inch laterals exist in the studied pressure zones, and these have a small replacement cost. Also, about one-third of all hydrants in the studied pressure zones will need to be replaced. For cost estimating purposes, the additional costs for lateral improvements and hydrant upgrades will be on the order of 3% to 5% of the pipe replacement costs.

4.2 HYDRAULIC ANALYSIS:

FIRE FLOW DURATIONS AND MULTIPLE FRONT CAPABILITY

The analyses presented in Section 4.1 address fire flow rates (gpm) available from single hydrants. However, fire flow rates are not the only measure of the water distribution system's fire emergency performance. Two other important factors are: 1) fire flow durations, and 2) multiple front capability. Limited fire flow durations and limited multiple front capability were evident in the October 1991 firestorm, even in pressure zones which substantially meet current UFC fire flow rate requirements.⁹

Fire flow durations reflect the total amount of water available for fire suppression in a given zone. Durations are commonly expressed (as in the UFC) as a fire flow rate and a time (for example, 1,500 gpm for 2 hours). Fire flow durations can be met by storage (for example, 1,500 gpm for 2 hours is 180,000 gallons), or by pumping into a zone at the fire flow rate, or by a combination of pumping and storage. Current District practice is to maintain sufficient water storage, as a separate fire fighting reserve in reservoirs (180,000 gallons), to meet the current UFC duration requirement (1,500 gpm for 2 hours in one- and two-family residential areas). In the October 1991 East Bay Hills Firestorm, fire flow durations were a problem: total water demand exceeded available supply and 10 reservoirs were emptied even though all pressure zones supplied water quantities well above the 180,000 gallons corresponding to the current UFC fire flow duration requirement.⁹ Therefore, we consider a range of alternative upgrade possibilities which provide greater fire flow durations.

→ (Multiple front fire suppression capability is the ability of a water distribution system to concurrently supply fire flows at more than one location within a pressure zone. The UFC does not contain a multiple front capability requirement. However, in the October 1991 firestorm, limited multiple front capability was a problem. As noted in the Phase I Final report,⁹ low flows were experienced at many hydrants in pressure zones at times when the reservoir(s) for the zone had water. This phenomenon, referred to as "overdrafting" occurs when pressure zones have significant amounts of small diameter pipes. In this case, hydrants near the water source may have strong flows, while other hydrants may concurrently have little or no flows. We consider a range of alternative upgrade possibilities which provide greater capability to support multiple fire suppression efforts concurrently within a single pressure zone.

In this section, we consider alternative upgrades to provide increased fire flow durations and enhanced multiple front fire suppression capability. For the purposes of hydraulic modeling, we consider fire flow durations of 3,000 gpm for 4 hours in a zone (720,000 gallons). For the purposes of modeling multiple front capability, we consider that the 3,000 gpm total fire flow within a zone is used by 2 hydrants each flowing 1,500 gpm simultaneously (with the 2 hydrants not less than 1,000 feet apart). For both fire flow duration and multiple front capability, there are a range of alternatives which are

⁹ VSP Associates, Inc. "East Bay Hills Firestorm Response Assessment, Phase I Final Report," July, 15, 1992.

improvements over the current system's performance. A discussion of desirable performance levels, considering the type and severity of fires expected within the District's service area, is given in Chapter 5.

In summary, the assumptions under which we consider a range of alternative upgrades for increasing fire flow durations and enhancing multiple front capability within a pressure zone are:

- Provide 3,000 gpm for 4 hours (720,000 gallons) in the zone.
- The 3,000 gpm flow is used by 2 hydrants flowing 1,500 gpm simultaneously. These two hydrants are at a distance over 1,000 feet apart.
- { • The 3,000 gpm for 4 hours (720,000 gallons total) is required to be a fire reserve (or pumping capacity) which is in addition to normal operation and emergency reserves, assuming build out of the zone.

The Amito pressure zone (A7B) was selected for this study of alternative upgrades. Five cases were evaluated; the Case 0 provides fire flow rates only, the other 4 cases explore different ways to provide increased fire flow durations and enhanced multiple front capability. The four latter alternatives differ in the combinations of storage and pumping required to meet these requirements; some of these alternatives result in performance levels lower than the target levels summarized above.. The cases studied are:

- Case 0. This base case alternative provides fire flows of 1,500 gpm to each hydrant (one flow at a time). This alternative provides fire flow rates only, and does not increase fire flow durations or multiple front capability. This alternative was described previously in Section 4.1.4.
- See ~~4.1~~
p4-21 • Case 1. Provide increased duration and multiple front capability, relying only upon existing fire reserve storage in the Amito zone; in this case, the fire flow duration which results at 3,000 gpm is only 113 minutes. Described in Section 4.2.1.
- Case 2a. Provide increased duration and multiple front capability, relying upon existing fire reserve storage in the Amito zone, and various levels of pumping at the Amito pumping plant. The pumping level at the Amito pumping plant is assumed to provide the fire flows only for the Amito pressure zone; in this case and the cases below, the fire flow duration at 3,000 gpm reaches 4 hours. Described in Section 4.2.2.
- Case 2b. Provide increased duration and multiple front capability, relying upon available fire reserve storage in the Amito zone, and pumping at the Amito pumping plant. The pumping level at the Amito pumping plant is sized to provide the fire flows for the entire Amito cascade, including simultaneous fire flows at 3,000 gpm in each of the Strathmoor, Gwin and Berkeley Hills pressure zones. Described in Section 4.2.3.
- Case 3. Provide increased duration and multiple front capability, relying upon

available fire reserve storage in the Amito zone, and a new tank in the Amito pressure zone. Described in Section 4.2.4.

- Case 4. Provide increased duration and multiple front capability, relying upon available fire reserve storage in the Amito zone, and a zone inter-tie to the Berkeley Hills pressure zone. Described in Section 4.2.5.

In modeling the multiple front capability, simultaneous fire flows from 10 pairs of hydrants were evaluated. The set of 10 pairs of hydrants was chosen, to approximate the worst case conditions in various parts of the pressure zone. The upgrades needed for this set of 10 analyses should encompass all other possible hydrant pairs. The ten pairs are as follows:

- Hydrants 10525 and 11922
- Hydrants 10525 and 3511
- Hydrants 10525 and 4931
- Hydrants 10525 and 13933
- Hydrants 10525 and 4032
- Hydrants 10525 and 11422
- Hydrants 16218 and 13320
- Hydrants 4032 and 4467
- Hydrants 13933 and 5039
- Hydrants 4931 and 11422

4.2.1 Case 1. Two Hydrants at 1,500 gpm, Existing Storage

The Case 1 analysis determines the necessary upgrades to provide 1,500 gpm simultaneously to 2 hydrants located over 1,000 feet apart (3,000 gpm total), relying only upon available fire reserve storage in the Amito zone.

The current Amito zone has two storage tanks: the Sherwick (400,000 gallons) and the Amito (493,000 gallons). During the October 1991 firestorm, the Amito tank was damaged. It is currently being re-designed; the replacement Amito tank will be approximately 650,000 gallons. The size of the new Amito tank was determined based on the limited size of the site. Once the new Amito tank is placed in service, the total storage in the Amito pressure zone will be 1.05 million gallons.

The total storage in the Amito pressure zone serves three purposes: normal operational use, emergency use, and fire reserve. For purposes of these analyses, we have assumed that only the fire reserve can be used for the 3,000 gpm combined two hydrant fire flows. In an actual fire, the actual amount of water used by fire fighters will not be restricted to just the fire reserve, but in fact to the entire amount of water available, including normal operational and emergency use amounts. We believe that it is prudent, for design purposes, to separate the fire reserves as additional reserves on top of normal operational and emergency reserves, as in an actual firestorm condition, real fire flows at all hydrants may substantially exceed even 3,000 gpm. For example, in the Amito pressure zone, during the October 1991 firestorm, actual peak flows were about

with old Amto, changing to 80-100% of band
gets another 1/2 hr at
3000 gpm

5,000 to 7,000 gpm for about 2 hours.

To determine the actual available fire reserves in this zone, we have used the water demand data from¹⁰ for the Amto pressure zone. The assumptions are as follows:

- There are (as of 1987) 603 equivalent dwelling units in the Amto zone.
- At build out, there are assumed to be 722 equivalent dwelling units. *Red Fly Paper (or fire weather)*
- The maximum day demand per equivalent dwelling unit is assumed to be between 620 gallons to 655 gallons, reflecting future water conservation and type of vegetation in the area.

$$650 \times 722 = 0.47 \text{ MG}$$

- Based upon the above water demands, the normal operational amount of water storage is 0.24 million gallons (MG), and the emergency reserve is 0.47 MG.
- The size of the Sherwick and old Amto tanks (0.89 MG total) was based upon the above normal and emergency reserves (0.71 MG total) and a fire reserve for 1,500 gpm for two hours (0.18 MG).
- As the replacement Amto tank is larger than the old Amto tank, the available fire reserve will be: $1.05 \text{ MG} - 0.71 \text{ MG} = 0.34 \text{ MG}$. Based upon a fire use of 3,000 gpm, this will provide a total of 113 minute duration.

actually 207 min.

The Amto pressure zone hydraulic model was run to determine what pipe upgrades are needed to allow simultaneous 1,500 gpm flows from two separated hydrants. Based upon these analyses, the following incremental upgrades above those described in Section 4.1.4 are needed:

40. (Upgrade 40). Same as upgrade 11, but the new pipe size is 12 inch, rather than 8 inch.
41. Same as upgrade 12, but the new pipe size is 12 inch, rather than 8 inch.
42. Same as upgrade 10, but the new pipe size is 8 inch, rather than 6 inch.
43. (New). Replace 680 feet of 6C27 pipe with an 8 inch pipe, on Alvarado Rd., between hydrants 4468 and 3525.
44. (New). Replace 266 feet of 6S24 pipe with an 8 inch pipe, on R/W 2613 between Gravatt Dr. and Grandview Dr.

By providing these upgrades, any pair of hydrants within the Amto pressure zone

¹⁰Draft Environmental Impact Report, DE-63, Water Distribution Facilities, Oakland Hills Area, EBMUD, 1987.

can be simultaneously flowed at 1,500 gpm each, while both the Amito and Sherwick tanks have storage. Depending upon which pair of hydrants are being flowed, different amounts of water is used from the Amito and Sherwick tanks. The main reason for this phenomenon is that the two tanks are linked together through a piping network having some flow restrictions. For example, if the two hydrants being flowed are H16218 and 13320 (both on Claremont Avenue), then water will flow mostly (over 95%) from the nearby Amito tank, with little flow (under 5%) from the distant Sherwick tank. Once the Amito tank is emptied, the water from the Sherwick tank would be used, but a combined flow of 3,000 gpm would not be possible. To make these two tanks float together better, an additional 1,400 feet of 8 inch pipe, upgrade 45, from the Sherwick tank, along Sherwick Rd, and along Charing Cross Rd., to the intersection with the 12 inch pipe on Tunnel Rd. would be needed. [Note: the Tunnel Rd. upgrade, from 6C36 to a 12 inch pipe, from hydrant 3511 to 11932, is currently being planned by the District, and is required to serve the services in the Amito zone until such time that the new Amito tank is placed in service. This Tunnel Rd. upgrade is included in the hydraulic models (including those in Section 4.1.4), but is not identified as an upgrade, as it is already in the District's budgeting process.]

4.2.2 Case 2a. Two Hydrants at 1,500 gpm, With Pumping

The Case 2a analysis determines the necessary upgrades to provide 1,500 gpm simultaneously to 2 hydrants located over 1,000 feet apart (3,000 gpm total) for 4 hours, relying upon available fire reserve storage in the Amito zone, plus additional water supply from the Amito pumping plant. (In these analyses, it is assumed that the Amito zone is not supplying any water to the three other pressure zones higher in the Amito cascade. Case 2b below explores the case when the Amito zone does supply water to the pressure zones higher in the Amito cascade).

As discussed in Section 4.2.1, the available fire reserve storage in the Amito zone only provides 113 minutes duration. In order to obtain a 4 hour duration, three analyses were performed, including three different amounts of pumping at the Amito pumping plant. The existing Amito pumping plant has 2 - 40 horsepower (HP) pumps, each capable of pumping about 600 gpm. The existing Amito pumping plant relies solely on offsite PG&E power (i.e., no backup power available).

- Analysis 1: assume that one of the two existing 40 HP pump is working at the Amito pumping plant, powered by an emergency backup power supply (upgrade 46). Duration is extended to about 147 minutes.
- Analysis 2: assume that the two existing 40 HP pumps are working at the Amito pumping plant, powered by an emergency backup power supply (upgrade 46). Duration is extended to about 200 minutes.
- Analysis 3: assume that the two existing 40 HP pumps, plus one new 25 HP pump are working at the Amito pumping plant (upgrade 47). Duration is extended to 4 hours. (Alternatively, the two 40 HP pumps could be replaced with larger 50 to 60 HP pumps). Either of these pumping alternatives provide the minimum

pumping capacity to extend duration to 4 hours.

In each of these three analyses, once the reservoirs are emptied, a smaller amount of water (that supplied solely by the pumps) would be available for fire flows.

In the October 1991 fire, PG&E power was lost to the Amito pumping plant (as well as to several other pumping plants). This loss of offsite power is not an unusual event. In most large fire conflagrations, it should be expected that one or more PG&E substations and transmission lines will be adversely affected, and that off-site power will not be available for several hours, to days. Similarly, in medium to large earthquake events, there is a high probability that PG&E power will be lost for hours, to days.

Therefore, if the District wants to rely on pumping to supply fire flows under earthquake or conflagration conditions, a reliable source of electric power must be factored into the design. This could be accomplished with an automatic emergency backup power supply at the pumping plant site, capable of supplying enough power to run all pumps. However, emergency generators are not 100% reliable and are subject to oxygen starvation in a major firestorm. Therefore, alternatives which rely on pumping to provide fire flows are not as reliable as options which rely entirely on gravity flow from storage.

see also 3-10 of Phase I

4.2.3 Case 2b. Two Hydrants at 1,500 gpm, With Pumping for Entire Cascade

The Case 2b analysis determines the necessary upgrades to provide 1,500 gpm simultaneously to 2 hydrants located over 1,000 feet apart (3,000 gpm total) for 4 hours, relying upon available fire reserve storage in the Amito zone, plus additional water supply from the Amito pumping plant. In these analyses, it is assumed that the Amito zone also has to simultaneously supply sufficient fire flow water to the three pressure zones higher in the Amito cascade.

In this analysis, we assume that no new storage reservoirs are built in any of the pressure zones in the Amito chain. Instead, all fire flows are available either from existing reservoirs, existing zone inter-ties, and new pumping.

The Amito chain consists of four pressure zones, with the following existing storage, pumping and inter-ties:

Zone	Existing Storage (Gallons)	Existing Fire Reserves (Gallons)	Existing Pumping Into Zone (GPM)	Existing Pumping Out of Zone (GPM)	Existing Inter-tie Into Zone (GPM)
A13B	400,000	180,000	550	0	0
A11A	500,000	180,000	750	550	0
A9B	500,000	180,000	830	750	1,500*
A7B	1,100,000**	390,000	1,250	830	0

* The inter-tie from B11A Pinehaven pressure zone through Caldecott regulator is currently capable of 1,200 gpm. The 1,500 gpm flow rate assumes the upgrades described in Section 4.1 of this report.

** The 1,050,000 gallon storage in the Amito pressure zone assumes that the new Amito tank (650,000 gallons) is in service.

In order to determine the amount of water needed to be pumped in the Amito chain, the fire reserves already available are calculated. It is assumed that the total fire reserves in the above table (930,000 gallons) plus a constant flow of 1,500 gpm for 4 hours through the Caldecott regulator are available (total 930,000 + 360,000 = 1,290,000 gallons).

If each of the four pressure zones must provide 3,000 gpm, simultaneously, for four hours, then the total fire reserves must be (3,000 gpm x 4 hours x 4 zones = 2,880,000 gallons). Thus, pumping into the Amito zone must be (2,880,000 needed - 1,290,000 available = 1,590,000 gallons) over a four hour period. Therefore, the Amito pumping plant must be able to provide 6,625 gpm, with a reliable power supply. Similar calculations for the Strathmoor A9B, Gwin A11A and Berkeley Hills A13B pressure zones results in the following:

Pressure Zone	Required Pumping Rate Into Zone (GPM)
A13B Berkeley Hills	2,250
A11A Gwin	4,500
A9B Strathmoor	5,250
A7B Amito	6,625

These required pumping rates are based upon several conservative assumptions, as follows:

- Only the fire reserve of 180,000 gallons in the A13B, A11A and A9B pressure zones was assumed. Actual normal operational demands plus emergency reserves are assumed to use the remaining storage. A detailed study of these three zones would probably show that at build out, the normal operational and emergency reserves are less than the total non-fire reserve storage in the existing tanks. Hence, the actual fire reserves may be somewhat higher.
- The B11A Pinehaven pressure zone is assumed to be able to supply 1,500 gpm for 4 hours through the Caldecott. While this is possible with current total storage in the B11A zone, this amount is more than the current fire reserves. Therefore, it is assumed that the "B" cascade (located about 1 mile south of the Amito "A" cascade) also is upgraded with reliable pumping plants, sized to be able to provide this flow into the "A" cascade.

A hydraulic analysis was performed for the Amito pressure zone, assuming that the Amito pumping plant is upgraded to be able to supply 6,625 gpm into the Amito zone, and that the Strathmoor pumping plant is upgraded to draw 5,250 gpm out of the Amito zone. The Amito pumping plant upgrade would require 4 - 200 HP pumps. (A fifth one would likely be needed as a spare).

The hydraulic analysis was performed assuming the same pipe upgrades as in Case 1. The results show that the 12 inch transmission pipe in the Amito zone would be loaded to very high levels. When the Amito pumping plant is operating at 6,625 gpm, the 12 inch pipe would have water velocities of 18 feet per second, and highest pressures of about 240 psi. Similar high velocities occur in the 12 inch feed from the Summit pressure zone into the Amito pressure zone. In addition, the transmission pipe in the Strathmoor and Amito zones, from the pumping plant to the tank, would have to be upgraded to a minimum of 12 inches. For the Amito pressure zone, the length of pipe from the pumping plant to the Amito reservoir is 5,300 feet. Additional lengths of pipe will still be subjected to pressures over 200 psi, and should be considered in the overall pumping plant upgrade.

The results of these analyses suggest that relying on existing storage, plus augmented pumping to provide simultaneous fire flows in both the Amito pressure zone and the other pressure zones higher in the cascade is probably impractical.

4.2.4 Case 3. Two Hydrants at 1,500 gpm, With New Tank in Amito Pressure Zone

The Case 3 analysis determines the necessary upgrades to provide 1,500 gpm simultaneously to 2 hydrants located over 1,000 feet apart (3,000 gpm total), relying upon available fire reserve storage in the existing Amito zone reservoirs, plus additional water from a new tank in the Amito zone.

Based upon the previous analyses, the northern portion of the Amito zone (along Claremont Avenue) is not able to supply a fire flow of 1,500 gpm at several different hydrants. The most seriously deficient hydrant is H-11422, on Gypsy Lane. As described in Section 4.1 of this report, five upgrades are needed in this area (upgrades 11 - 15) in order to increase fire flows to 1,500 gpm at each hydrant. These five upgrades involve a total of 2,134 feet.

A logical location for a new tank is along Claremont Avenue, located at the 960 ± foot elevation. This would require 2,400 feet of new pipe (upgrade 51) on Claremont Avenue, plus the acquisition of a suitable property. A closer nearby site that the District already owns is slated for proposed Telegraph tank; however, this site is at a higher elevation, and would require a separate pumping plant to fill the reservoir and a regulator to reduce pressure for use in the zone..

The Amito zone was analyzed including a 330,000 gallon tank at the Claremont location. By installing the tank at this location, four of the five upgrades in the Claremont Avenue area are no longer needed. The net result is that upgrades 15 and 51 are required in this area (total length of 2,708 feet), plus the new tank, as compared to the Case 0 upgrades 11 - 15 (total length of 1,826 feet).

By not installing upgrades 11 - 14, the new tank will not float well with the Amito and Sherwick tanks. The new tank will be the last to fill. Alternatively, by adding upgrades 11 - 14 (another 1,826 feet of pipe), the tank will float better.

4.2.5 Case 4. Two Hydrants at 1,500 gpm, With Zone Inter-tie to Berkeley Hills Pressure Zone

The Case 4 analysis determines the necessary upgrades to provide 1,500 gpm simultaneously to 2 hydrants located over 1,000 feet apart (3,000 gpm total), relying upon available fire reserve storage in the existing Amito zone reservoirs, plus additional water from a new zone inter-tie between the Amito and Berkeley Hills pressure zones.

As will be described in Chapter 5 of this report, it is recommended that the Berkeley Hills tank (currently 400,000 gallons) be replaced with a much larger tank (about 2,500,000 gallons). The purpose of this larger tank will be to supply water to adjacent pressure zones, through regulators and zone inter-ties, in order to substantially increase fire flow durations.

The Amito zone can be tied into the Berkeley Hills pressure zone by a 5,130 foot long 8 inch pipe (upgrade 53) from Grizzly Peak Boulevard, along Claremont Avenue, to hydrant 13320. The high pressure from the Berkeley Hills zone (300 psi) will require a high pressure pipe. A pressure regulator should be used to reduce the pressure to about 90 psi just above hydrant 13320 (upgrade 55).

4.2.6 Summary of Amito Pressure Zone Modeling Results

For the A7B Amito pressure zone, hydraulic analyses were conducted to evaluate five alternative cases to improve fire flow durations and multiple front capability. With pipe replacements as outlined in the preceding sections, all of the following alternatives can meet the objective of enhancing multiple front capability. However, the various alternatives differ significantly in their ability to provide the desired increase in fire flow duration. The principal conclusions are:

Case 1. Relying on existing fire reserve storage

- There is insufficient water storage to provide the desired increase in fire flow duration.

Case 2a. Relying on existing fire reserve storage, plus pumping to provide fire flows for the Amito zone only.

- Pumping plant enhancements are required, which is less reliable than relying on water storage to provide fire flows.

Case 2b. Relying on existing fire reserve storage, plus pumping to provide fire flows for the Amito zone and other zones higher in the cascade.

- Requires pumping at very high rates; impractical.

Case 3. Relying on existing fire reserve storage, plus a new reservoir in the Amito zone.

- Provides the desired increase in fire flow duration.

Case 4. Relying on existing fire reserve storage, plus an inter-tie to the Berkeley Hills pressure zone.

- Provides the desired increase in fire flow duration.

A summary of the pipe replacements and other hardware upgrades required to implement these alternative upgrades is given in Table 4-14.

Estimates of the costs of these alternatives are given in Table 4-15. The costs presented in Table 4-15 are based on the District-provided costs (Tables 5.3.1a and 5.3.1b), and the following additional cost information:

- The cost of a backup emergency power supply is about \$375,000-\$450,000, including the cost of the hardware, installation, inspection and design, for the existing Amito pumping plant.
- The cost to upgrade the Amito pumping plant from 2-40 HP pumps, by either adding a third pump, or upsizing the existing pumps, to about 120 HP total, is about \$225,000 to \$300,000, which includes the cost to upgrade the electrical switchgear.
- The cost to build a new approximately 6,000 gpm pumping plant is about \$850,000, which includes demolition of the existing pumping plant and the design costs. The incremental cost to provide an on-site emergency power supply would probably be about \$300,000. In addition, an Environmental Impact Report would likely be required (at additional cost), probably taking about 6 months to complete.

The cost implications of the various alternative upgrades for the Amito pressure zone are as follows:

1. Five different alternatives were studied (as described above). To provide multiple fire flows, at least a 23% increase in cost over Case O (which addresses only fire flow rates) is needed.
2. To provide multiple fire flows and a minimum four hour duration, the four

alternatives (Cases 2a, 2b, 3, 4) are 68%, 220%, 117%, and 207% higher in cost as compared to Case 0. The percentage increase in costs would be even higher if improved float between tanks is desired.

Although the Case 4 and Case 2b options have similar cost, the reliability of Case 4 (all duration provided by storage) is higher than Case 2b (duration provided by pumping). In addition, the pumping option may cost substantially more, if the 12 inch transmission pipes need to be upgraded.

The Case 3 costs are lower than the Case 4 costs, yet provide the same total duration, all through storage. However, to implement the Case 3 scenario, a new tank would likely need to be built in every pressure zone. In the Oakland Hills areas, there are other restrictions which may prove this to be a less viable option, such as limited site selections, neighborhood opposition to view obstructions and construction, etc. Each new tank would likely require an EIR process. Further, in detailed design, the Case 4 option could be somewhat less expensive, by providing emergency regulators or zone gates at each pumping plant all the way up to the Berkeley Hills zone, to allow flow of water from upper zones to reach lower zones.

The Case 2a alternative is the least costly of the options which provide 4 hour durations, but this case would only suffice to provide such duration in the Amato zone. In the October 1991 firestorm, three of the four zones in the Amato chain ran out of water. Therefore, this alternative would have improved flow durations during the 1991 fire, but only in about one-third of the area that needed additional water.

Based upon these results, it is suggested that a combination of additional reservoirs in each zone (Case 3) or a large reservoir at the top of a cascade (Case 4) be constructed to provide the required fire flows and durations. On a zone-by-zone basis, the actual design should be controlled by minimizing costs. These costs are mostly controlled by local topography and existing infrastructure.

The option to provide the required fire flows and durations through pumping will result in a higher capital cost, higher operational costs, and with somewhat lower reliability of service. However, in instances where a pressure zone is not part of a cascade, and is located immediately above a zone with a large, reliable source of water (such as the gravity Aqueduct zone), the Case 2a alternative (single zone pumping with reliable back up power) would be an attractive alternative.

Table 4-14
Amito Pressure Zone A7B Alternative Upgrades (Part 1 of 3)

UPGRADE DESCRIPTION	NEW 6 IN. FEET	NEW 8 IN. FEET	NEW 12 IN. FEET	NOTES
CASE 0: Current Fire Flow (single 1500 gpm at any hydrant)				
6 Replace 6CM50		285		
7 Replace 6SMM61		1144		
8 Replace 6C27		344		
9 Replace 6C27		445		
10 Replace 6C27	554			
11 Replace 6C26		314		
12 Replace 6SMM58		207		
13 Replace 6SMM58		883		
14 Replace 6SMM58		422		
15 Replace 6SMM58		308		
TOTALS	554	4352		
CASE 1: 2 x 1500 gpm Using Storage Only in A7B (limited to 113 minutes)				
6 Replace 6CM50		285		Same as Case 0
7 Replace 6SMM61		1144		Same as Case 0
8 Replace 6C27		344		Same as Case 0
9 Replace 6C27		445		Same as Case 0
42 Replace 6C27		554		Same as Case 0 upgrade 10, except larger diameter
40 Replace 6C26			314	Same as Case 0 upgrade 11, except larger diameter
41 Replace 6SMM58			207	Same as Case 0 upgrade 12, except larger diameter
13 Replace 6SMM58		883		Same as Case 0
14 Replace 6SMM58		422		Same as Case 0
15 Replace 6SMM58		308		Same as Case 0
43 Replace 6C27		680		New
44 Replace 6S24		266		New
45 Replace 8SMM63/8SMB			1400	Optional, to improve float between Amito and Sherwick Reservoirs
TOTALS		5331	521	(Totals exclude optional item)

Table 4-14
Amito Pressure Zone A7B Alternative Upgrades (Part 2 of 3)

UPGRADE DESCRIPTION	NEW 6 IN. FEET	NEW 8 IN. FEET	NEW 12 IN. FEET	NOTES
CASE 2a: 2 x 1500 gpm x extended durations with pumping, 1 zone only				
6 Replace 6CM50		285		Same as Case 0
7 Replace 6SMM61		1144		Same as Case 0
8 Replace 6C27		344		Same as Case 0
9 Replace 6C27		445		Same as Case 0
42 Replace 6C27		554		Same as Case 0 upgrade 10, except larger diameter
40 Replace 6C26			314	Same as Case 0 upgrade 11, except larger diameter
41 Replace 6SMM58			207	Same as Case 0 upgrade 12, except larger diameter
13 Replace 6SMM58		883		Same as Case 0
14 Replace 6SMM58		422		Same as Case 0
15 Replace 6SMM58		308		Same as Case 0
43 Replace 6C27		680		New
44 Replace 6S24		266		New
45 Replace 8SMM63/8SMB			1400	Optional, to improve float between Amito and Sherwick Reservoirs
TOTALS		5331	521	(Totals exclude optional item)
46 Amito PP: 1 - 40 HP existing pump with reliable power supply				Duration = 147 minutes at 3000 gpm, 600 gpm thereafter
46 Amito PP: 2 - 40 HP existing pump with reliable power supply				Duration = 200 minutes at 3000 gpm, 1200 gpm thereafter
47 Amito PP: 2 - 40 HP exist plus 1 - 25 HP new pump, with reliable power supply				Duration = 240 minutes at 3000 gpm, 1400 gpm thereafter
CASE 2b: 2 x 1500 gpm x 4 hour minimum with pumping for 4 zones in cascade				
6 Replace 6CM50		285		Same as Case 0
7 Replace 6SMM61		1144		Same as Case 0
8 Replace 6C27		344		Same as Case 0
9 Replace 6C27		445		Same as Case 0
42 Replace 6C27		554		Same as Case 0 upgrade 10, except larger diameter
40 Replace 6C26			314	Same as Case 0 upgrade 11, except larger diameter
41 Replace 6SMM58			207	Same as Case 0 upgrade 12, except larger diameter
13 Replace 6SMM58		883		Same as Case 0
14 Replace 6SMM58		422		Same as Case 0
15 Replace 6SMM58		308		Same as Case 0
43 Replace 6C27		680		New
44 Replace 6S24		266		New
45 Replace 8SMM63/8SMB			1400	Optional, to improve float between Amito and Sherwick Reservoirs
TOTALS		5331	521	(Totals exclude optional item)
48 Amito pumping plant: 4 new 200 HP pumps with reliable power supply				Upgrade Amito PP to 6625 gpm
49 Strathmoor, Gwin and Berkeley Hills Pumping Plant upgrades				Upgrade Pumping Plants to 5250, 4500, 2250 gpm, respectively
50 Replace 6000 feet of 12" pipe in A7B with 16" to 24"				Optional to reduce pressures and velocities

Table 4-14
Amito Pressure Zone A7B Alternative Upgrades (Part 3 of 3)

UPGRADE DESCRIPTION	NEW 6 IN. FEET	NEW 8 IN. FEET	NEW 12 IN. FEET	NOTES
CASE 3: 2 x 1500 gpm x 4 hours (Storage only in A7B with new tank)				
6 Replace 6CM50		285		Same as Case 0
7 Replace 6SMM61		1144		Same as Case 0
8 Replace 6C27		344		Same as Case 0
9 Replace 6C27		445		Same as Case 0
42 Replace 6C27		554		Same as Case 0 upgrade 10, except larger diameter
15 Replace 6SMM58		308		Same as Case 0
43 Replace 6C27		680		New
44 Replace 6S24		266		New
45 Replace 8SMM63/8SMB			1400	Optional, to improve float between Amito and Sherwick Reservoirs
51 New Pipe on Claremont Ave		2400		New
TOTALS		6426		(Totals exclude optional item)
52 New 330,000 Gallon Claremont Tank				New
CASE 4: 2 x 1500 gpm x 4 hours (All from storage, including transfer from A13B)				
6 Replace 6CM50		285		Same as Case 0
7 Replace 6SMM61		1144		Same as Case 0
8 Replace 6C27		344		Same as Case 0
9 Replace 6C27		445		Same as Case 0
42 Replace 6C27		554		Same as Case 0 upgrade 10, except larger diameter
15 Replace 6SMM58		308		Same as Case 0
43 Replace 6C27		680		New
44 Replace 6S24		266		New
45 Replace 8SMM63/8SMB			1400	Optional, to improve float between Amito and Sherwick Reservoirs
53 New Pipe on Claremont Ave		5130		New high pressure pipe
TOTALS		9156		(Totals exclude optional item)
54 New Berkeley Hills Tank				2,500,000 gallons
55 New Amito Regulator				1 - 2" and 1 - 6", reduce 300 psi from A13B to 90 psi in A7B

Table 4-15
Cost of Amito Pressure Zone Upgrades to Higher Standards

Alternative	Pipes \$K	Pumps \$K	Tanks \$K	Regulator \$K	Laterals Hydrants \$K	Total \$K
Case 0. 1500 gpm x 1 hydrant x 2 hours	585				29##	614
Case 1. 1500 gpm x 2 hydrants x 113 minutes	720 (937)*				29	749
Case 2a. 1500 gpm x 2 hydrants x 4 hours,pumped	720 (937)*	225 - 300			29	1012
Case 2b. 1500 gpm x 2 hydrants x 4 hours, entire cascade,pumped	720 (937)* (1,867)**	1,150+			29	1,899
Case 3. 1500 gpm x 2 hydrants x 4 hours, with in-zone storage only	771 (988)* (1,207)@		500		29	1,300
Case 4. 1500 gpm x 2 hydrants x 4 hours, with storage from top of cascade	1,099*** (1,316)*		500#	200	29	1,828

Notes

* Extra \$217K to improve float between Amito and Sherwick tanks after one tank is emptied

** Extra \$930K to upgrade 12" transmission pipe in Amito zone to allow high flow rates

*** Could be reduced if regulators installed in each zone, and A9B and A11A zones are upgraded to the same level.

@ Extra \$219K to improve float between new Claremont and Amito tanks

Pro-rate share of cost of new 2,500,000 gallon Berkeley Hills tank. This new tank would also serve the A11A, A9B, B13Aa and B11A zones, as described in Section 5 of the report.

Costs for laterals and hydrant improvements estimated at 5% of Case 0 pipe replacement cost.

+ Costs for pumps in the A9B, A11A, A13B zones are additional

5.0 DISTRIBUTION SYSTEM UPGRADES: ANALYSIS AND RECOMMENDATIONS

5.1 Hazards Facing the District

The major hazards facing the District's water distribution system were reviewed in Chapter 2. These hazards include: fire, earthquake, power outages, ground failure, dam failure, freeze, floods, contamination of water supplies, and hazardous material incidents. However, the focus of the recommended distribution system upgrades discussed in this chapter is on enhancing the system's response capability for fire. The impact of the recommended upgrades on the water distribution system's response capability for the other hazards is briefly reviewed at the end of this chapter.

The detailed hydraulic modeling of the distribution system which has been conducted for this project was of nine pressure zones involved in the October 1991 fire; in addition, the District has conducted detailed analyses of two other pressure zones involved in the fire. Therefore, the primary focus of the recommended upgrades is on the 1991 fire area, with extrapolations to other similar, high-hazard areas elsewhere in the District's service area. Specifically, this study focuses primarily on the hill areas (generally east of Highway 13) along with "base of the hills" areas west of Highway 13. In this report, the term "hill area" is used to denote the high hazard areas, both east and west of Highway 13, where wildland/urban intermix fires are a significant threat.

The major types of fire threats facing the District's hill areas were reviewed in Chapter 3, Hazards Assessment. Briefly, the three major types of fire threats are categorized as:

- 1) "normal" structure fires,
- 2) wildland/urban intermix fires, and
- 3) fire following earthquakes.

Each of these major types of fires places different demands on the water distribution system with respect to total water demand, fire flow rates and durations necessary, single vs. multiple front fire suppression requirements, and expected number of pressure zones involved. Therefore, different types of system upgrades may be necessary to address these three different types of fire threats. Nevertheless, possible distribution system upgrades generally enhance, at least to some degree, the system's fire suppression capability for all types of fire threats.

5.2 Distribution System Upgrades: Concepts

The water distribution system in the hill areas of the District differs significantly from the system in the "flatlands" areas of the District where the density of development is generally higher than in the hill areas. Most significantly with respect to fire emergency capability, service regions above about 325 feet in elevation are pumped pressure zones in

puzzling focus on water supply after than flow

which water is pumped up to storage reservoirs and then fed by gravity flow to customer services (or hydrants). In contrast, lower elevation zones (about 60% of the District's customers) are fed directly by gravity flow from treatment plants. Thus, the lower zones have a (virtually) unlimited supply of water (except possibly following a major earthquake, see Section 3.3), while the higher elevation pumped zones have finite (limited) water supplies, depending on storage and pumping capacities.

Within the hill areas, the reservoir system is "cascaded" with successively higher elevation reservoirs supplied by pumping from lower elevation pressure zones. The highest elevation pressure zones are supplied by five stages of pumping from the Wildcat, Sequoia or Claremont Tunnel aqueducts. Reservoirs low in the cascades are much larger than those higher in cascades, because the lower reservoirs serve much larger populations and also supply the higher reservoirs. For example, in the firestorm area, lower reservoirs typically contain 1.5 million to several tens of millions of gallons, while higher reservoirs typically contain 200,000 to 500,000 gallons.

This seems more important to me

Other characteristics of the water distribution system in the hill areas also differ from those in the flatlands. Because of the lower development density in hill areas, normal water demands are much lower and therefore pipe diameters are smaller. Furthermore, because of the lower service density and the rugged topography of the hills, cross-linking (looping) of mains is much less prevalent in the hills than in the flatlands. The combination of limited water storage, smaller pipes and limited cross-linking of mains results in substantially lower water flow capacities (including total fire flow durations) available in a given hill area pressure zone than in lower gravity flow zones.

As reviewed in the Phase I report, experience in the October 1991 firestorm indicates three principal limitations in the existing water distribution system's fire response capability in the hill areas:

- i) limited flows from older, small diameter pipe areas,
- ii) limited water storage (and/or pumping capacity, transfer between zones), and
- iii) limited ability to concurrently supply fire flows in more than one section of some pressure zones (overdrafting).

Desirable upgrade alternatives address one or more of these limitations in the existing water distribution system's fire response capability. Conceptually, there are three main types of water distribution system upgrades under consideration:

- i) increase fire flow rates (gallons per minute) from hydrants,
- ii) increase fire flow durations (hours), and
- iii) increase multiple front capability (concurrent fire flows in more than one section of each pressure zone).

The Technical Advisory Panel for this project, including the Fire Chiefs of Oakland and

Berkeley, has concurred with the desirability of the above three types of system upgrades. The Fire Chiefs believe that increasing fire flows from low flow hydrants should be the highest priority upgrade.

In the present context, "conceptual" upgrade means the desired objective (e.g., increase fire flow rates). For each of these types of conceptual system upgrades, there may be several alternative engineering strategies to achieve the desired performance enhancement. For example, longer fire flow durations in a given pressure zone could be achieved by increasing water storage, by increasing pumping capabilities, by augmenting interconnections with nearby zones, or by some combination of these alternatives. Specific alternative upgrades are discussed in Section 5.3. First, however, the types of conceptual upgrades which are effective in enhancing system performance for the three main types of fire threats are reviewed.

a) "Normal" Structure Fires

For "normal" structure fires, fire flow (gallons per minute) is the predominant measure of desired water distribution system performance. Fire flow standards (UFC) and guidelines (ISO) are for single-structure fires with the intent of confining a fire to the structure or block of origin. For "normal" structure fires, the underlying assumption is that the recommended performance levels (fire flows) are those sufficient for single-site fire suppression efforts.

The UFC fire flow requirements allow higher fire flow standards to be set for high hazard areas. For one-and two-family residential areas, the normal UFC fire flow requirement is 1,000 gpm for two hours. For fire flows of 1,000 or 1,500 gpm, we assume (to be conservative) that these are single-hydrant fire flows. Implicit in the UFC and explicit in the ISO guidelines, however, is the assumption that the required fire flows can be provided by one or more nearby hydrants. For example, the ISO guidelines state that fire flows considered are those from fire hydrants within 1000 feet of the fire (measured as hose can be laid by apparatus).

In the District's service area, 1,500 gpm, two hour fire flows are being considered for some high fire hazard areas. This higher fire flow standard also augments, to at least some degree, the system's capability for larger fires. The prospective 1,500 gpm fire flow standard for new construction in the Oakland high-hazard areas has been the subject of considerable confusion. The Oakland City Manager's office, Fire Department, Office of Emergency Services, and the District believed that a 1,500 gpm standard was in place for new construction. However, the 1,500 standard has not yet been formally enacted. As per the provisions of the UFC, the Oakland fire chief is in the process of preparing findings to justify the increased fire flow standard, for submission to the City. Because of these developments, and the fact the District has been designing new construction distribution systems in the hill areas to a 1,500 gpm standard for a number of years, we consider the 1,500 gpm standard as the "proposed standard" to be used for comparison of upgrade alternatives.

Water system upgrades to improve fire response capability for normal structure

fires which are considered in this study include: extending the 1,500 gpm fire flow standard throughout the District's high hazard areas and upgrading older portions of the system to current standards or to another standard higher than when built. Extending the proposed 1,500 gpm fire flow standard throughout the District's high hazard areas would help to ensure that all future distribution system construction projects provide a high fire suppression capability. Upgrading older portions of the distribution system would ensure better fire suppression capability for future structure fires and also have some benefit for wildland/urban intermix fires and fires following earthquakes.

Under the UFC, fire flow standards are set by fire agencies and the District is the water supplier not the standard setter. We strongly encourage the District to continue to work actively with all of the fire agencies within its service area and to encourage the fire agencies to delineate high hazard areas with uniform criteria and to set uniform fire flow standards for new construction in these areas. We recommend that the fire flow standard for new construction be established at 1,500 gpm in high hazard hill areas.

b) Wildland/Urban Intermix Fires

*means what?
see p 5.1*

The UFC fire flow standards are designed for single-structure fires. Experience in the 1991 fire as well as in other fires indicates that major wildland/urban intermix fires will place water demands on the system which far exceed those in the UFC fire flow standards. Major wildland/urban intermix fires typically require larger total water quantities and longer fire flow durations than for single-structure fires, and supply of water to multiple fronts concurrently. Effective suppression of major wildland/urban intermix fires requires a well-coordinated response by well-trained, well-equipped fire personnel as well as sufficient water supplies.

Fire flow standards higher than 1,500 gpm are not recommended to enhance fire suppression capability in major wildland/urban intermix fires. 1,500 gpm is about the practical limit that firefighters can use effectively from a single hydrant and 1,500 gpm provides strong fire suppression capability in the vicinity of the hydrant. Rather than further increases in fire flow rates, effective suppression of major wildland/urban intermix fires requires longer fire flow durations and ability to support concurrent fire suppression efforts at more than one location in each pressure zone.

Therefore, water system upgrades under consideration to enhance the system's performance capability for wildland/urban intermix fires include: increased water storage, increased pumping or transfer capabilities between zones, longer fire flow durations, and assuring the system's ability to provide fire flows concurrently at more than one location in each pressure zone.

c) Fire Following Earthquake

For fire following an earthquake, the underlying assumption is that multiple structure fires are possible. In the ideal world, the water distribution system would have adequate fire suppression capability for multiple fires and be seismically resistant so that

critical facilities remain functional after an earthquake. In reality, given limited financial resources, the District must balance the allocation of resources between upgrades which will improve performance in single structure fires, upgrades which will improve performance for major wildland/urban intermix fires, and upgrades to improve post-earthquake performance (fire and other water service).

Water system upgrades under consideration for fire following earthquake are similar to those for wildland/urban intermix fires: increased water storage, pumping or transfer capabilities to achieve longer fire flow durations, and assuring the system's ability to provide fire flows concurrently at more than one location in each pressure zone. For fire following earthquake, the system's ability to function after the earthquake (seismic hardening) is also critically important. However, as noted above, this is expensive and financial resources need to be balanced with other needs. The District has an ongoing Seismic Evaluation Program; therefore, post-earthquake performance of the water distribution system is not considered in detail in this report.

d) Effectiveness of Upgrade Alternatives

Table 5.2.1 provides an overview of the major conceptual system upgrades and their impact on enhancing the system's fire response capability. Virtually all upgrades have some beneficial impact on the system's fire performance capability. However, particular upgrades may have much more or less impact on some types of fires than on other types.

Table 5.2.1 Impact on Distribution Systems Fire Suppression Capability			
UPGRADE OBJECTIVE	Normal Structure Fires	Wildland/urban intermix fires	Fire Following Earthquake
increase hydrant flows	substantial	significant	significant
increase duration	little	substantial	substantial ?
multiple-front capability	little	substantial	substantial
enhance seismic survivability	little	little	major

In the table above, the impact of prospective upgrades on the system's fire performance capability is judged on a four-point subjective scale for the three major types of fire threats under consideration: little (marginal improvement), significant (definitely positive enhancement), substantial (very positive enhancement), and major (major augmentation of performance). Enhancing seismic vulnerability is included in the table above to emphasize

the degree of exposure which the District faces and to acknowledge that from the District policy perspective seismic upgrades must be considered as well as upgrades for enhancing fire suppression capability.

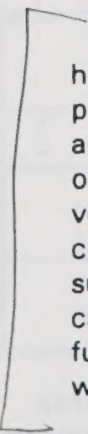
5.3 Alternative Distribution System Upgrades: Fire Flow Rates

Hydraulic modeling results for nine of the fire area pressure zones were presented in Chapter 4. These results indicate available fire flows from each hydrant: a) in the current system, and b) after making selected improvements. The "current system" fire flow results are based on the existing distribution system, plus a few upgrades which have already been approved for construction.

The approximate costs of implementing the recommended upgrades outlined above have been estimated using unit-cost estimates provided by the District. These are total cost figures, including engineering design, construction, and District overhead charges. These unit-cost estimates are summarized in Table 5.3.1a,b. Several alternatives are evaluated for upgrading hydrants.

a) Upgrading All Hydrants to 1,500 or 1,000 gpm

For the nine pressure zones modeled, the upgrades necessary to bring hydrants up to the proposed standards for new construction of 1,500 gpm for high-hazard areas and 1,000 gpm elsewhere are summarized in Tables 5.3.2a,b,c, along with cost estimates using the unit cost data in Table 5.3.1a,b. There are a total of 59 low flow hydrants, of which 30 are below 1,000 gpm. The hydraulic analyses on which these pipe upgrade recommendations are based were summarized in Chapter 4 which includes hydrant by hydrant analyses of the specific pipe segments where upgrades are necessary. In total, bringing hydrants up to the proposed fire flow standards for new construction requires replacing about 16,000 feet of pipe at a cost of approximately \$2 million.



The recommended upgrades in Table 5.3.2a are the minimums necessary to bring hydrants up to the proposed standards for new construction. About one-third of the total pipe lengths recommended to be installed is 6" pipe. Installing 8" pipe instead would augment the system's ability to provide fire suppression water concurrently at more than one location within the zone (see Section 5.5). The cost to upgrade to 8" instead of 6" is very small, only about \$75,000 for the nine zones, as shown in Table 5.3.2b. In consideration of the added benefits (enhanced capability for concurrent multiple front fire suppression) and small cost, this alternative warrants consideration. Multiple front capability is discussed in Section 5.5; further upsizing to 12" on pressure zone backbones further enhances the system's ability to provide concurrent fire flows at multiple locations within a pressure zone.

If particular lengths of pipe are to be replaced, then installing a minimum size of 8" pipe generally appears desirable, unless water-quality concerns counter-indicate and require smaller pipes. In other cases (e.g., a single hydrant on a short piece of pipe), little marginal benefit may be obtained by upsizing from 6" to 8".

Table 5.3.1a Unit Cost Estimates for Pipe Replacements per Linear Foot¹	
Pipe Diameter	Unit Cost Per Linear Foot²
6"	\$113
8"	\$120
12"	\$155

Footnotes:

¹Data provided by the District (November 5, 1992).

²In addition to pipe replacements, other upgrades such as improved laterals and new hydrants will have to be done. Such costs will add about 5% to the pipe costs shown above.

Table 5.3.1b Cost Estimates for Reservoirs and Pumping Plants¹	
Reservoir 0.7 million gallon ²	\$1,450,000
Reservoir 1.0 million gallon ²	\$1,550,000
Reservoir 2.0 million gallon ²	\$1,850,000
Reservoir 5.0 million gallon ²	\$2,650,000
Pressure regulator ³	\$200,000

Footnotes:

¹Data provided by the District (November 5, 1992)

²Steel reservoir with valve pit, 30,000 cubic yards of excavation, and 1,000 foot paved access road.

³Typical cost.

Table 5.3.2a
Alternative Fire Flow Upgrades for Each of the Nine Zones
(All Hydrants to 1,500 or 1,000 gpm as Proposed Standards for New Construction)¹

ZONE	6" Pipe Feet	8" Pipe Feet	12" Pipe Feet	Approximate Cost
A13B Berkeley Hills	0	0	0	none
A11A Gwin	0	971	0	117,000
A9B Strathmoor	0	0	0	none
A7B Amito	554	4352	0	\$585,000
A5A Summit	0	0	0	none
B13Aa Hilltop	539	278	0	\$94,000
B11A Pinehaven	120	910	0	\$123,000
B9A Thornhill	2383	1370	1081	\$596,000
B7A Joaquin Miller	1711	1724	0	\$400,000
TOTALS	5307	9605	1081	\$1,914,000

TOTAL FEET OF PIPE REPLACEMENT REQUIRED: 15,993 **Estimated cost: \$1.9 million**

Footnote:

¹Hydrants flows at a residual pressure of 20 pounds per square inch.

Table 5.3.2b
Alternative Fire Flow Upgrade (8" minimum)

All nine zones	6" Pipe Feet	8" Pipe Feet	12" Pipe Feet	Approximate cost
TOTAL	0	15,234	1081	\$1,990,000

Table 5.3.2c
Alternative Fire Flow Upgrades for Each of the Nine Zones
(Upgrade sub-1,000 gpm hydrants to proposed standards for new construction)¹

ZONE	6" Pipe Feet	8" Pipe Feet	12" Pipe Feet	Approximate Cost
A13B Berkeley Hills	0	0	0	none0
A11A Gwin	0	502	0	\$60,000
A9B Strathmoor	0	791	0	\$95,000
A7B Amito	0	4621	0	\$555,000
A5A Summit	0	0	0	none
B13Aa Hilltop	539	0	0	\$61,000
B11A Pinehaven	0	910	0	\$109,000
B9A Thornhill	2383	1370	1081	\$596,000
B7A Joaquin-Miller	0	1724		\$207,000
TOTALS	2922	9918	1081	\$1,682,000
TOTAL FEET OF PIPE REPLACEMENT REQUIRED: 13,921				Estimated cost: \$1.7 million

Footnote:

¹These estimates are based on the hydraulic modeling conducted to assess upgrades of all hydrants to 1,500 gpm. These estimates are approximate and are based on professional judgement of which pipe segments would have to be replaced compared to those replaced for the upgrade of all hydrants. Therefore, these estimates are not as accurate as those shown in Tables 5.3.2a or 5.3.2b. However, the conclusion that nearly as much pipe would have to be replaced is sound because nearly all of the sub-1,000 gpm hydrants are at the ends of mains and therefore hydrant flow upgrades require replacement of intermediate pipes between the water source and the low flow hydrants.

b) Upgrading Only Sub-1,000 gpm Hydrants

The upgrades summarized in Tables 5.3.2a and 5.3.2b assume that all hydrants are brought up to the proposed standards for new construction (1,500 or 1,000 gpm, depending on location). However, there are alternative upgrade strategies which merit consideration. For single-structure fires, 1,000 gpm is an adequate hydrant flow for fire suppression (as expressed in the UFC standards and ISO guidelines). Therefore, the District may wish to consider upgrading only hydrants which have flows below 1,000 gpm, rather than upgrading all hydrants which are below 1,500 gpm in high hazard areas. There are two sub-alternatives: 1) upgrade low flow hydrants below 1,000 gpm to 1,500 gpm, or 2) upgrade low flow hydrants below 1,000 gpm to 1,000 gpm. Either of these alternatives would be somewhat less expensive than upgrading all sub-1,500 gpm hydrants to 1,500 gpm, because less pipe replacement would be required.

However, upgrading low-flow hydrants to 1,000 gpm may not make sense from two perspectives: first, once the upgrade is undertaken, the marginal cost to upgrade to 1,500 gpm is generally low, and second, upgrading to 1,500 (which requires larger diameter pipes than upgrading to 1,000 gpm) has additional benefits. Specifically, the larger pipe diameters would, in addition to providing larger single hydrant flows, also enhance the systems' ability to provide fire suppression water concurrently at more than one fire front in a single pressure zone. This enhancement arises because the larger pipes have smaller residual pressure drops when the first hydrant is utilized, thus allowing greater flows from subsequent hydrants (see Section 4.2 for hydraulic modeling examples).

For these reasons, we consider a possible upgrade of only those hydrants with flows currently below 1,000 gpm, but when such upgrades are done, upgrade to 1,500 gpm. The approximate estimated lengths of pipe to be replaced under this alternative, and estimated costs, are shown in Table 5.3.2c. Nearly 14,000 feet of pipe would have to be replaced at a cost of nearly \$1.7 million (more than 85% of the cost of upgrading all low flow hydrants to the current standards). Therefore, nearly as much pipe must be replaced to upgrade the sub-1,000 hydrants to 1,500 gpm as to upgrade all of the sub-1,500 hydrants to 1,500. Therefore, this alternative does not appear attractive and it appears to be better policy to upgrade all sub-1,500 gpm hydrants in high-hazard areas to the current standard of 1,500 gpm.

Upgrading sub-1000 gpm hydrants to 1,000 gpm is another possible upgrade alternative. This alternative does not appear particularly attractive, for the same reasons as upgrading sub-1,000 gpm hydrants to 1,500 gpm: 1) it requires nearly as much pipe replacement as upgrading all hydrants to 1,500 gpm, and 2) upgrading to 1,000 gpm does not have the benefits of enhancing fire suppression at more than one location concurrently in a pressure zone. Therefore, we do not consider this alternative further.

5.4 Alternative Distribution System Upgrades: Fire Flow Durations

Enhancing the distribution system's performance capability for major wildland/urban intermix fires requires increasing fire flow durations. Enhancing the distribution system's performance capability for fire following earthquake also requires enhancing fire flow durations and seismic hardening. The need for increased durations is clearly evidenced from the 1991 fire in which all the water (firefighting reserves, plus emergency reserves, plus the operating water) in 10 distribution system reservoirs was consumed by firefighting efforts and ruptured services.

The District and other water agencies have predominantly used the UFC standards and ISO guidelines which have two-hour fire flow durations for one- and two-family residential areas (see Section 2.3.4 and 2.3.5). For major wildland/urban intermix fires, we suggest that a four hour duration standard is more appropriate. This recommended four hour duration is derived from two observations. First, based on the 1991 fire and other wildland/urban intermix fires, a given pressure zone is likely to be under fire threat for several hours; two hour durations do not provide sufficient fire flow duration. Second, in a major conflagration, it is likely to take several hours for fire suppression equipment and personnel to be fully organized and deployed. A four hour fire flow duration should provide sufficient time to organize resources of personnel and equipment. With longer fire flow durations, District and fire response personnel should have adequate time to determine where more water was needed and to use emergency pumps, portable water systems, or pumps on fire apparatus to move water from where it is available to where it is needed to supplement that obtainable from storage.

At 1,500 gpm, a two hour fire flow duration requires 180,000 gallons of water. Doubling the duration to four hours requires doubling the fire reserve water available, to 360,000 gallons. However, in addition to requiring longer fire flow durations for effective fire suppression, major wildland/urban intermix fires are also highly likely to require concurrent suppression activity at more than one front within a given pressure zone. Therefore, we suggest that the fire flow standard for high hazard residential area pressure zones be established as 3,000 gpm (allowing two 1,500 gpm fire suppression actions) for four hours. Under this proposed standard, a total fire reserve water supply of 720,000 gallons per pressure zone would be required. The suggested standard is consistent with total water demands experienced by pressure zones in the 1991 fire; most zones experienced demand of at least 3,000 gpm for several hours as the fire burned through each zone (see Phase I report for zone by zone details).

The proposed fire standard of a 3,000 gpm fire flow for four hours is four times the current UFC-based standard for high hazard areas. However, as discussed above, and as shown by the 1991 fire experience, the UFC standard is inadequate for the major fires experienced in the District's hill areas. It is also important to note that the larger pressure zones at lower elevations in the hill areas generally have sufficient water storage to provide the proposed higher standard. Therefore, upgrades are needed primarily for the smaller pressure zones at higher elevations.

Increased fire flow durations (i.e., increased total water available) in any given pressure zone can be accomplished by water storage within the zone, interconnects to

other pressure zones, pumping into the zone, emergency pumping into the zone, or by a combination of these means. The current storage, pumping, and interconnection situation for the nine fire area pressure zones for which hydraulic modeling has been conducted are shown in Table 5.4.1, along with data for the Dingee and Broadway Terrace zones.

Fire flow durations available in each of these zones depend on a wide variety of assumptions, including fire flow rate, reservoir fill levels, other water demands, pump situation (normal, emergency, or none), regulator status, the water situation in source zones, and so on. Water distribution system fire flow design criteria for single-structure fires assume using fire reserves only, and not water in the emergency reserve or operating band. At present, the B9A Thornhill-Forestland pressure zone cannot meet the 180,000 fire reserve requirement. Each of the other zones (or source zone for regulator zones) currently has a minimum of 180,000 gallons of fire reserve water.

Increasing fire flow durations in the nine zones under consideration could be accomplished by various combinations of increased storage, increased pumping capacity (normal or emergency) and increased interconnections with other zones. Meeting fire flow and duration requirements by storage is the most conservative design approach, because hydrants are then fed by gravity flow from reservoirs (or through regulators). Pumping (normal or emergency) can augment fire flows and durations available from storage, but pumping is inherently less reliable due to the possibility of power failures, or pump failures, or damage to facilities due to a major firestorm. Furthermore, emergency generators may be rendered inoperable during a firestorm by oxygen starvation. Therefore, we recommend that fire flows and durations be provided primarily by storage.

In addition, there is another reason why relying on pumping to provide fire flows and durations is not recommended. Major wildland/urban intermix fires simultaneously involve more than one pressure zone. Therefore, relying on pumping into a zone to provide fire flow and duration requirements is not recommended, unless sufficient pumping capacity is provided to ensure pumping to meet simultaneous fire flow demands in an entire cascade. Pumping at the desired fire flow rate does not provide fire flows if several zones in a cascade are involved: for example, a given zone could be receiving 1,500 gpm from below while pumping 1,500 gpm into the next higher zone and thus have no net water available for fire suppression.

Pumping to provide for simultaneous fire flows in each zone of a cascade requires progressively more pumping at lower levels in the cascade. For example, to provide simultaneous 1,500 gpm fire flows in each zone of a cascade would require 7,500 gpm into the base zone, 6,000 gpm into the second zone, 4,500 into the third zone, 3,000 gpm into the fourth zone, and 1,500 gpm into the fifth (top) zone. For 3,000 gpm in each zone, these pumping rates would have to be doubled. Pumping at rates as high as these (either 1,500 or 3,000 gpm case) would require significant upgrades to pumping plants and pipe upsizing as well.

For the nine zones being considered, recommendations for possible upgrades to improve fire flow durations are summarized in Table 5.4.2. The objective of these upgrades is to provide the capability within each zone to provide 3,000 gpm for four hours. We note that any improvement in available durations is positive and would help in

Table 5.4.1
Current Water Feed Information

Pressure Zone	Storage in zone (gallons)	Fire reserves in zone (gallons)	Pumping capacity into zone (gpm)³	Pumping capacity from zone (gpm)^{3,4}	Other water feeds? (gpm)
A13B Berkeley Hills	400,000	180,000	550	0	none
A11A Gwin	500,000	180,000	750	550	none
A9B Strathmoor	500,000	180,000	830	750	Bristol Reg. (1,500) Caldecott Reg. (1,200)
A7B Amito	890,000 ⁵	180,000	1,250	830	none
A5A Summit ¹	1,500,000	180,000	3,400	1,530	none
B13Aa Hilltop	250,000	180,000	350	none	none
B11A Pinehaven	710,000	180,000	480	350	none
B9A Thornhill-Forestland	190,000	Note ²	none	480	Thornhill Reg. (600)
B7A Joaquin-Miller ¹	3,600,000	180,000	6,100	3330	none
B5A Dingee ¹	5,960,000	180,000	13,300	3750	none
B4Aa Broadway Terrace	none	none	none	none	Buena Vista Reg. ⁶ Broadway Terrace Reg. ⁶ (1,000)

Footnotes:

¹These pressure zones are large, with several reservoirs that may not float together; the information included in the table is for the 1991 firestorm and nearby areas only.

²In its current configuration, with a temporary regulator replacing a landslide-destroyed pipe feeding water from the Forestland Reservoir, this zone does not have 180,000 gallons of fire reserves.

³Pumping capacity is the maximum assuming that all pumps are operating.

⁴Several zones also feed regulators; operation of these regulators reduces total water available within these zones.

⁵The Amito Reservoir, which has a capacity of 490,000 gallons, is being replaced and upsized to about 650,000 gallons.

⁶The flow rates available through these regulators is estimated at about 1,000 gpm each, but these estimates have not been verified by field tests.

Table 5.4.2
Recommended Fire Flow Duration Upgrades⁴

Pressure Zone	Recommended Upgrade	Approximate Cost
A13B Berkeley Hills	install new 2,500,000 gallon reservoir Inter-tie A13B and B13Aa (2,500' of 12" pipe) also inter-tie B13Aa and B13A zones (4,800' of 12" pipe)	\$2,000,000 \$387,500 \$744,000 ¹
A11A Gwin	install regulator from A13B zone	\$200,000
A9B Strathmoor	install second reservoir 700,000 gallons	\$1,450,000
A7B Amito	several alternatives: see Section 4.2	varies ¹
A5A Summit	no changes needed	none
B13Aa Hilltop	accomplished under A13B	none
B11A Pinehaven	install regulator from B13A upsized reservoir to 500,000 gallons	\$200,000 \$1,350,000 ¹
B9A Thornhill-Forestland	upsized Thornhill reservoir to 400,000 gals reconnect to Forestland reservoir	\$1,000,000 ¹ \$100,000
B7A Joaquin Miller	no changes needed	none
TOTAL₃		\$4,888,500 to \$8,201,500²

Footnotes:

¹For the lowest cost option, \$4,537,500, the footnoted items are omitted; A7B Amito uses Case 4 (Section 4.2).

²For the highest cost option, \$8,201,500, all items in the table are included; A7B Amito uses Case 3 (Section 4.2).

³The reservoir upgrades in B11A and B9A are lower priority recommendations than the others. Excluding these, the total cost estimate is approximately \$6 million.

⁴These costs are for fire flow duration upgrades only, excluding costs to upgrade hydrants or enhance multiple front capability.

suppression of major wildland/urban intermix fires. Furthermore, augmentation of fire flows and durations available from storage does not eliminate the need for emergency pumping capacity. Emergency pumping capacity would still be required for unusually prolonged or severe fires or to concentrate water resources into areas of highest demand for fire suppression water.

The recommended 3,000 gpm for four hours fire flow duration standard would provide four times the current fire reserves maintained to meet a 1,500 gpm two hour fire flow standard. However, despite this four-fold increase, the higher fire flow standard would not provide unlimited water; in extreme fire emergencies, demand may exceed even this high level. For example, in the A7B Amito zone water demand during the 1991 fire exceeded 5,000 gpm for two hours and this high demand level would probably have continued if water had been available. In this context, we note that the 3,000 gpm four hour fire flows are not the only source of water for fire suppression. First, pumping capacity (normal or emergency) may augment total water available. Second, for some zones additional water is available from regulators drawing from other pressure zones. Third, in an extreme emergency such as the 1991 fire, water in the operating band and emergency reserve water will also be used for fire suppression. The District implicitly recognizes this through the Red Flag program in which reservoirs' operating bands in high hazard areas are to be raised on high fire risk days.

The 3,000 gpm four hour duration is a significant enhancement beyond the current fire flow duration requirement which will significantly improve the system's performance in major wildland/urban intermix fires. However, as in any practical system, water limitations may still occur in exceptionally extreme events.

Two of the nine pressure zones (B5A Summit and B7A Joaquin Miller) have sufficient total water storage within the zone to meet the current operating band and emergency reserve requirements (total 1.5x maximum daily demand) and still have more than 720,000 gallons of water remaining for fire use. The other seven pressure zones require upgrades to meet the proposed higher duration fire flow standard. The recommended upgrades are summarized in Table 5.4.2 and discussed below for each of these pressure zones.

A13B Berkeley Hills

The Berkeley Hills pressure zone is served by a temporary 400,000 gallon redwood tank installed in 1973. The Hilltop (B13Aa) and Roundtop (B13A) reservoirs are also temporary redwood tanks installed in 1973. The District is considering linking these zones together. A principal benefit would be to substantially increase fire flow durations available. We suggest that an approximately 2.5 million gallon reservoir be built at the Berkeley Hills site and that two or three of these zones be linked together: A13B could be linked to B13Aa, B13Aa could be linked to B13A, or all three could be connected. The 2.5 million gallon reservoir size was selected to provide increased fire flow durations for several pressure zones. One large reservoir is less expensive than several smaller ones; furthermore, in many zones siting a new reservoir at an appropriate elevation is difficult or impossible.

The Hilltop reservoir has a lower overflow elevation than those for the Berkeley Hills, Roundtop, and Skyline reservoirs; therefore, the Hilltop reservoir could be removed from service or isolated from the resulting zone by suitable valving. There are relatively few services in these high-elevation zones and therefore water quality concerns may be an issue. The proposed new reservoir could be reserved for emergency fire use or used for normal water supply with water cycling as necessary to preserve water quality.

To intertie the A13B Berkeley Hills and B13Aa Hilltop pressure zones, 2500 feet of new 12" pipe would need to be installed on Grizzly Peak Blvd. from Marlborough Terrace to Grizzly Terrace Drive. To intertie the B13Aa Hilltop and B13A Roundtop zones, 4800 feet of new 12" pipe would need to be installed on Grizzly Peak Blvd. from the Hilltop reservoir to R/W 1712. If either of these interties is made, then the amount of pipe replacement necessary to bring hydrants in the B13Aa zone up to current fire flow standards is slightly reduced. Depending on whether or not the Hilltop reservoir is retained, then slightly less (81 to 118) feet of 6CM46 pipe would not need to be upgraded to improve hydrant fire flows.

The Berkeley Hills, Hilltop, and Roundtop reservoirs are all redwood tanks installed in 1973 as emergency facilities. These redwood tanks are prone to failure in large earthquakes. The Hilltop tank presents an inundation hazard to nearby residences. Replacing these tanks would also improve seismic hardening and enhance post-earthquake fire suppression capabilities.

A11A Gwin

The current Gwin reservoir site does not appear adequate to support a substantially larger reservoir and a suitable site for a second reservoir is not evident within this pressure zone. Therefore, augmenting fire flow durations may most readily be accomplished by installing a regulator to feed A11A from A13B (a pressure zone in which new interties and storage increases were recommended above in the discussion of the A13B Berkeley Hills pressure zone).

A9B Strathmoor

Augmenting fire flow durations in this pressure zone would be most readily accomplished by adding a second reservoir with approximately 700,000 gallons of capacity. An apparently suitable site is available on Tunnel Road. The Strathmoor pressure zone is also fed by two regulators: the Bristol Regulator which draws water from the Gwin Pressure Zone and the Caldecott Regulator which draws water from the Pinehaven Pressure Zone. However, relying on water supplied through these regulators for fire suppression within Strathmoor would correspondingly reduce the fire flow durations in the Gwin and Pinehaven pressure zones.

A7B Amito

The current 490,000 gallon Amito tank is scheduled to be replaced with an approximately 650,000 gallon tank. Several detailed alternative ways of increasing fire flow durations in the Amito zone were studied and presented in Section 4.2.

B13Aa Hilltop

Recommended fire flow duration enhancements would be accomplished by implementation of the recommendations outlined under the A13B Berkeley Hills pressure zone (interties and new reservoir).

B11A Pinehaven

Recommended fire flow duration enhancements could be accomplished by installing a regulator to feed water into B11A from B13Aa (particularly if the interties and upgrades to A13B and B13A are implemented). This is a relatively low-cost alternative, but may be over-extending the total fire reserves available in a major wildland/urban intermix fire were to involve concurrently the A13B, B13Aa, B13A, A11A and B11A pressure zones. However, installing a new reservoir on Tunnel Road in the A9B Strathmoor pressure zone would be partially offsetting, by eliminating or reducing water demand for A9B from B11A through the Caldecott regulator. A more conservative alternative would be to upsize Pinehaven #1 reservoir to the maximum possible on the existing site, about 500,000 gallons or to add a third reservoir if a suitable site can be found.

B9A Thornhill-Forestland

There are two alternatives which would suffice to meet the recommended fire flow duration requirements. First, the existing Thornhill Reservoir could be upsized to the maximum possible on the site, about 400,000 gallons (to provide an additional 200,000 gallons of fire reserves). Second, the B9A pressure zone could be reconnected to the Forestland Reservoir. The link to Forestland was broken in an early 1980s landslide and a "temporary" fix was implemented by installing the Thornhill regulator. At present, fire flow durations in this zone appear to be significantly substandard and enhancements are strongly recommended. Reconnection to Forestland is possibly the lower cost option and is thus recommended. With an upgraded Thornhill regulator and access to the storage in B11B, fire flow durations in the B9A zone would be very good. However, the City of Oakland would have to make roadway improvements and stabilize the landslide area for this option to be feasible.

Summary of Fire Flow Duration Upgrades

As shown in Table 5.4.2, there is a range of upgrade alternatives for the nine pressure zones studied, with cost estimates ranging from about \$4.9 million to about \$8.2

million. The \$4.9 million alternative is the minimum to have the system's capability approach the target performance capability of 3,000 gpm for four hours in each zone. With only this level of upgrade, the system cannot provide these fire flow durations simultaneously in all of the nine zones. The addition of another reservoir in A7B is highly recommended, and the additional intertie between B13Aa and B13A improves ability to move water within the "B" cascade is also recommended. However, the additional storage suggested for B11A and B9A provides a relatively small augmentation of fire flow durations at a relatively high cost and thus these upgrades are definitely lower priority than the other. Excluding the B11A and B9A storage upgrades the total costs for these nine zones is about \$6 million. The \$6 million estimate is probably more realistic than the maximum estimate of \$7 million.

5.5 Recommended Distribution System Upgrades: Multiple-Front Capability

Providing effective multiple front fire suppression capability requires a substantial increase in total fire flow quantities (rate times duration) for each zone and the capability to deliver fire flows concurrently at more than one location within a pressure zone. The two attributes (fire flow rate and fire flow duration) are effectively considered in the two previous recommended upgrade sections which covered fire flow rates and fire flow durations. However, in addition to consideration of the total fire flow water quantities available in a zone, multiple-front capability necessitates the distribution system being able to concurrently supply fire flows at least any two locations within a zone. A pressure zone which can supply adequate fire flows at any two locations concurrently can also supply (lesser) fire flows at multiple locations concurrently. Specifically, we propose that the objective be to provide capability for:

concurrent fire flows of 1,500 gpm at any two hydrant locations in a pressure zone which are more than 1,000 feet apart (with distance measured as firefighters would lay hose from apparatus).

The requirement of providing adequate fire flows at any two locations concurrently requires either large pipe diameters within a zone or multiple water feeds into a zone. How large pipe diameters must be and how many water feeds are required depend on the specific layouts of each zone and there is a high multiplicity of possible alternatives.

The alternative we have adopted, which is suitable for cost estimation purposes, is to provide a "backbone" in each zone of large pipe, 12" in most cases. The backbone includes pipe from the pumping plant to the reservoir and major links to zone extremities. Most other pipe segments should be 8", with 6" pipe acceptable in short segments only. A greater extent of smaller pipes (6" or 8") can be acceptable in some cases where there are two or more water feeds into a pressure zone or in areas where the mains network is more highly interconnected.

The multiple front objective is well beyond current design basis in residential areas and will require substantial pipe replacements. The benefits of this upgrade would be derived principally from large urban/wildland intermix fires involving canyon regions where

multiple fronts are expected and to a lesser degree from fire following earthquake. Because this upgrade would upsize pipes between pumping plants and reservoirs, this upgrade would also substantially enhance the maximum possible pumping rates from either normal or emergency pumping (if large capacity pumps were installed or available).

An estimate of the upgrades recommended to enhance multiple front fire suppression capability are given below for each of the nine pressure zones and summarized in Table 5.5.1, along with cost estimates. Before implementation, these preliminary detailed engineering studies should be completed, including consideration of water quality issues.

A13B Berkeley Hills

The Berkeley Hills pressure zone has a single length of 12" diameter pipe which suffices to provide multiple front fire suppression capability throughout the zone. No upgrades are recommended.

A11A Gwin

The Gwin pressure zone has a 12" pipe from the reservoir to the junction near hydrant 5295, with 8" pipe westward to the Gwin pumping plant and a combination of 6" and 8" pipe southward towards the Bristol regulator. This zone has reasonably good multiple front capability as is. However, better capability would be provided by upsizing the pipe between the Gwin pumping plant and hydrant H5295 to 12" and by upsizing the pipe between H5295 and the Bristol regulator to 12". Approximately 4400 feet of 12" would be required.

A9B Strathmoor

Enhancing multiple front capability in the Strathmoor zone requires upsizing pipe to 12" between the Strathmoor pumping plant and reservoir. Approximately 1000' of pipe should be upsized to 12"

A7B Amito

This pressure zone was analyzed in detail as described in Section 4.2. Enhancing multiple front capability requires 425 feet of 8" pipe and between 521 and 1921 feet of 12" pipe.

A5A Summit

The portion of the Summit zone involved in the fire (and considered in this analysis) has a backbone of 12" or larger pipe. There are, however, several segments of pipe which

Table 5.5.1
Upgrades for Multiple Front Capability¹

Pressure Zone	Upgrade Required²	Cost Estimate
A13A Berkeley Hills	NONE	NONE
A11A Gwin	4,400 feet of 12" pipe	\$682,000
A9B Strathmoor	1,000 feet of 12" pipe	\$155,000
A7B Amito	425 feet of 8" pipe 521 - 1921 feet of 12" pipe	\$132,000 to \$349,000
A5A Summit	0 to 1,700 feet of 12" pipe	\$0 to \$263,500
B13Aa Hilltop	0 to 800 feet of 12" pipe	\$0 to \$124,000
B11A Pinehaven	2,500 feet of 12" pipe	\$387,500
B9A Thornhill-Forestland	6,000 feet of 12" pipe	\$930,000
B7A Joaquin Miller	6,200 feet of 12" pipe	\$961,000
TOTALS	24,100 FEET OF 12" PIPE to 26,600 FEET OF 12" PIPE	\$3,247,500 to \$3,852,000
NET COST³	Assuming that low flow hydrant upgrades are made, the <u>additional</u> net cost to improve multiple front capability is reduced.	approximately \$2.0 million

Footnotes:

¹These estimates assume completing a 12" backbone between pumping plants and reservoirs in each zone and upsizing other major links to 12".

²Assumes that upgrades discussed in Section 5.3 have been made.

³Assuming that low flow hydrants are to be upgraded to current standards; net costs assume substitution of 12" replacements for smaller pipe upsizings recommended in Section 5.3 for low flow hydrant upgrades.

⁴Incremental cost to implement Case 1 (Section 4.2) for the Amito zone.

probably should be upsized to 12": between H361 and H227 (about 800'), between H1743 and H13417 (about 300'), and between the 12" pipe near H3801 and H3791 (about 600'). Therefore, pipe lengths ranging from none to 1700' of pipe would have to be upsized to 12".

B13Aa Hilltop

If this pressure zone is connected to A13B and the Hilltop reservoir is kept in service, then no further upgrades would be required. If the Hilltop reservoir is removed from service and B13Aa is not connected to B13A then about 800' of pipe from H4550 to the southern end of the recently-installed 12" pipe north of H19013 should be upsized to 12".

B11A Pinehaven

Enhancing multiple front capability in this zone requires upsizing the pipes between the Pinehaven pumping plant and the Pinehaven reservoirs to 12" along Broadway Terrace (about 2000'). In addition the segment from Broadway Terrace westward to H4062 (about 500') should also be upsized to provide multiple front capability for hydrants in the western and southern ends of this zone. Therefore, a total of approximately 2,500 feet of pipe would have to be upsized to 12".

B9A Thornhill-Forestland

Enhancing multiple front capability in this zone requires completing the 12" backbone between the Thornhill regulator and the Thornhill reservoir by upsizing the pipe between the regulator and H3476 (about 1500'). In addition, the loops in the southwestern corner of the zone are undersized to provide multiple front capability. A new 12" backbone should be installed from the reservoir along the western edge of the zone to H3577 (about 4500'). Therefore, a total of about 6,000 feet of pipe would have to be upsized to 12".

B7A Joaquin Miller

The northern portion of this zone which was involved in the October 1991 firestorm is included in this analysis. To enhance multiple front capability, the link between the Montclair pumping plant and the existing 12" north of H12116 should be upsized to 12" to complete the 12" backbone between the pumping plant and the reservoir. This segment, along the path which includes H2843, H2842 and H12116 requires about 3300' of new 12" pipe; if this upgrade were installed then the District's planned B7A 16" upgrade east of Highway 13 would be unnecessary. The net length of new pipe required is thus only about 500'. Multiple front capability in the loops which include H3684 and H3678 may require more connections to the 12" backbone. Short segments of 12" pipe between the backbone and H3678, between H3576 and H3685, and between H4273 and

the 12" backbone would probably suffice (total about 700'). Enhancing multiple front capability in the loops in the western portion of the modeled area of this requires upsizing a considerable segment of pipe between H12116 and H3040 continuing northward through H3252 (about 5000' of pipe). Therefore, a total of about 6,200 feet of pipe would have to be upsized to 12".

5.6 Extrapolation of Recommended Upgrades to Other High Hazard Areas within the District

Clearly, there are additional areas within the District, besides those considered in the current analysis, which are similar high-hazard fire areas. High fire hazard residential hill areas are those where a combination of high vegetative fuel loads, steep topography, limited access and narrow streets, and non-fire safe construction practices combine to produce unusually high fire hazards. However, delineation of exactly what areas of the District constitute high hazard areas has not yet been done. The cities of Oakland and Berkeley have specifically designated high fire hazard areas; other cities have not.

Under the Uniform Fire Code, designation of high hazard areas is the responsibility of the Fire Chief in each fire agency. It would, therefore, be inappropriate for the District to unilaterally designate areas as high hazard. Rather, the District should cooperate with the fire agencies within its service area and strongly encourage the fire agencies to adopt uniform definitions and delineations of high hazard areas.

The above paragraph notwithstanding, it is possible to outline approximately those portions of the District's service area which are generally high hazard areas. In Oakland, the designated high hazard areas include the hills east of Highways 13 and 580 along with heavily vegetated regions in the foothills regions west of these highways. The Berkeley-designated high hazard areas follow a similar classification of the heavily vegetated hills and foothills. Similar terrain is found northward along the hills through Kensington and El Cerrito and southward through Piedmont, San Leandro, San Lorenzo, Castro Valley and the Hayward portions of the District's service area. In the northern portion of the service area, the hilly regions south of Highway 80 towards San Pablo reservoir could be classified as high hazard. East of the Oakland-Berkeley hills, much of the highly-vegetated hilly regions of Orinda, Moraga, and Lafayette should probably also be considered high fire hazard areas. Further east, the hill regions along the western side of Highway 680 also probably fit the high hazard criteria. More review by fire agencies is needed to determine vegetative fuel loads, road conditions, building practices and the other factors which govern high hazard designations. Under recent legislation (the Bates bill, AB-337), fire agencies are directed to undertake evaluation of high hazard areas.

The designation of high hazard areas should be done by the fire agencies, in a uniform and consistent manner, throughout the District's service area. However, for the purposes of making rough extrapolations of the extent and cost of upgrades similar to those recommended in the nine pressure zones analyzed in detail in the remainder of the District's high hazard areas, we use the areas outlined in the previous paragraph. Depending on exactly where the high hazard area boundaries are drawn, we estimate that there are about 500 to 700 miles of distribution system pipe in the high hazard areas. For

the purposes of estimation we shall use 600 miles as the approximate amount of pipe in these preliminarily defined high hazard areas.

At present, nine pressures zones (or parts thereof) have been analyzed in the current project and the District has also completed analyses and upgrade recommendations for two additional pressure zones (Broadway Terrace and Dingee). Within these 11 zones, the percentage of pipe replacement necessary to upgrade hydrant fire flows varied markedly from none in some pressure zones (Berkeley Hills) to an average of about 7% in the nine zones, to about 11% in Dingee to about 42% in Broadway Terrace. Overall, for these 11 pressure zones the necessary replacement percentage is about 11.5%. Clearly, the necessary percentage of pipe replacement will vary from pressure zone to pressure zone depending heavily on the amount of small and older pipe currently in place. Overall, however, the 11.5% replacement figure is probably a reasonable estimate.

For the area preliminarily designated as high hazard, which contains about 600 miles of pipe, the necessary replacement percentage is probably between 10 and 15%. Therefore, approximately 60 to 90 miles of pipe probably have to be replaced in order to bring these areas up to the same fire flow standards as applied in the nine pressure zones analyzed (i.e., 1,500 gpm in high hazard residential areas and 1,000 gpm in borderline high hazard residential areas). At an average cost of \$120/foot, this pipe replacement would cost about \$650,000 per mile (including a few percent extra for other hardware needed) or about \$40 to \$60 million for the entire high hazard area.

For the nine zones analyzed in this study, the estimated costs to increase fire flow durations to the recommended standard of 3,000 gpm for four hours, range from \$4.9 million to \$8.2 million, with \$6.0 million being a more-realistic high estimate. These nine zones, plus the other two zones analyzed by the District (where no storage upgrades are required) total about 70 miles. If similar costs per mile of distribution system pipe apply throughout the high hazard areas, then the District-wide total cost of fire flow duration upgrades would be about nine times \$4.9 million to \$6.0 million, or approximately \$45 to \$55 million (assuming 600 miles of pipe in high-hazard areas). Similar estimates are obtained by considering that there are approximately 19 pumped cascades in the high hazard area. Assuming that most of these cascades require additional water storage, particularly at higher elevations, suggests costs in the \$40 million range (for example, a 2.5 million gallon reservoir costs about \$2 million). With other storage upgrades lower in zones, regulators, interconnects, and such, then a total cost estimate of \$45 million to \$55 million appears reasonable.

For the nine zones analyzed in this study the estimated costs to enhance each pressure zone's capability to support multiple front fire suppression activity were approximately \$3.5 million. However, much of the pipe replacements duplicate those required to upgrade low flow hydrants. Therefore, the incremental cost (assuming that low flow hydrants are upgraded) to also enhance multiple front capability is significantly reduced. The net cost of enhancing multiple front capability would be approximately 55% of the \$3.5 million, or approximately \$2 million. These nine zones modeled (plus portions of adjacent zones considered) contain about 43.8 miles of pipe. If similar costs per mile of distribution system pipe apply throughout the high hazard areas, then the District-wide total cost of multiple front enhancements would be approximately 14 times \$2 million, or

about \$28 million (assuming 600 miles of pipe in high hazard areas). Given the uncertainties in these extrapolations, we estimate the costs as \$20 million to \$30 million.

The nine zone cost estimates and the District-wide high hazard residential hill areas estimates are summarized in Table 5.6.1. The total estimated costs District-wide for making the three types of distribution system upgrades (fire flows, fire flow durations, multiple front capability) range from \$100 million to \$150 million. For the nine zones analyzed and the two zones analyzed by the District, the cost estimates are quite accurate because detailed hydraulic modeling has been done to establish the current performance of the water distribution system in these areas. The extrapolation to the remainder of the District's high hazard residential hill areas has considerably more uncertainty because the boundaries of the high hazard area have not been precisely defined and no hydraulic modeling has been conducted for these areas. We believe, however, that these are realistic estimate which do indicate the approximate costs involved in these upgrades.

5.7 Financing the Recommended Upgrades

The estimated total costs for all three upgrades (upgrading flow hydrants, increasing fire flow durations, and enhancing multiple front fire suppression capability) total approximately \$100 million to \$150 million. The three types of recommended upgrades all represent prospective fundamental changes in District policy with respect to bringing old portions of the system up to current fire flow standards and with respect to exceeding UFC provisions for high hazard areas. Therefore, these prospective policy changes also require consideration of the financial aspects of these recommendations. Ultimately, the central question becomes "Who pays?"

The magnitude of the funding required to implement the recommended upgrades, \$100 million to \$150 million mandates that the upgrade program be relatively long term. For the purposes of discussion, we consider a 20-year program. Over 20 years, the upgrades require spending approximately \$5 million to \$7.5 million per year.

In the absence of external sources of funding (e.g., state or federal) there are only three primary options for allocating the costs of the recommended upgrades:

- 1) District-wide throughout the customer base, or
- 2) locally, within the areas which benefit directly, or
- 3) a combination of these alternatives.

The District's water revenues are approximately \$200 million per year. Therefore, if allocated District-wide, an additional expenditure of \$5 million to \$7.5 million per year, would correspond to rate increases of several percent. The preliminarily designated high hazard area corresponds fairly closely to the pumped pressure zones, which encompass about 40% of the District's total customer base. If the upgrade cost were allocated among the pumped pressure zone service areas, then the percentage rate increases would be about 2.5 times higher than if the costs were allocated District-wide.

Table 5.6.1
Extrapolated Costs
District-Wide High Hazard Areas

UPGRADE	COST ESTIMATES (MILLIONS OF DOLLARS)	
	ENTIRE HIGH-HAZARD AREA ¹	11 FIRE-AREA PRESSURE ZONES
INCREASE HYDRANT FLOWS RATES TO PROPOSED STANDARDS	\$40 - \$60	\$6
INCREASE FIRE FLOW DURATIONS (720,000 gallons storage)	\$45 - \$65	\$5 - \$6 ²
ENHANCE MULTIPLE FRONT CAPABILITY	\$20 - \$30	\$2 ³
TOTAL COSTS	\$105 - \$145	\$13 - \$14

Footnotes:

¹Costs for the entire high hazard residential area, including the nine pressure zones modeled in detail and the Dingee and Broadway Terrace pressure zones.

²As discussed in Section 5.5, some of the recommended upgrades to improve fire flow duration have lower priority. \$6 million is probably a realistic upper bound for the nine zones considered.

³Net additional cost for multiple front capability, assuming that upgrading low flow hydrants to current standards is implemented.

Whether funding is undertaken District-wide or locally, there are two alternatives for the District. First, the District could choose a "pay-as-you-go" basis in which annual expenditures for upgrades are covered by rates and charges and/or annual assessments. This alternative is highly recommended for District-wide costs because the total cost to the District and its customers would be minimized. Furthermore, if the upgrades are implemented over a 20-year period, there would not be a need for large sums which could be raised in a bond offering. Second, the District could issue bonds to cover the capital costs. If the bonds alternative were selected, then there would be various types of bond-financing available to the District including general obligation bonds, special tax bonds (Mello-Roos), special assessment bonds, or revenue bonds. These types of alternative bond-financing vehicles have recently been discussed.¹ If some upgrade costs are allocated locally, rather than District-wide, then bond funding would probably be necessary to avoid large charges to a local area in the year in which upgrades in that area were implemented.

We recommend a combination of District-wide and local funding for these upgrades.

5.7.1 Normal Replacements

Over a 20-year period, there may be a some amount of "normal" replacement of pipe and other facilities for maintenance and other reasons. We suggest that the portion of an upgrade project that would have been done anyway for "normal" reasons be allocated District-wide. For example, if a normal pipe replacement would have been with a 6" pipe and the fire upgrade requires an 8" pipe, then the costs of a 6" pipe should be allocated District-wide.

5.7.2 Upgrade Hydrant Flow Rates

The first recommendation is to upgrade hydrant flow rates. Current District policy is to charge beneficiaries when portions of the system are upgraded to beyond the initial as-when-built standard. This policy could be continued for fire flow upgrades. Alternatively, fire flow upgrade costs could be allocated District-wide. Very recently, the District has undertaken detailed studies of upgrades of low flow hydrants in the Broadway Terrace and Dingee Pressure zones. In these cases, the final allocation of costs have not yet been determined.

5.7.3 Upgrade Fire Flow Durations and Multiple Front Capability

The alternative upgrades for fire flow duration and multiple front fire suppression capability go well beyond current standards for new construction. Such upgrades directly reflect the higher than normal risk inherent in the high hazard hill areas. Therefore, we suggest that costs for these upgrades be allocated locally to those who benefit from the upgrades.

East Bay Municipal Utility District, memo from Jorge Carrasco (General Manager) to Board of Directors, July 13, 1992.

5.8 Emergency Management Issues

The analyses of the distribution system presented in Chapter 4 and the detailed recommendations discussed above focus on permanent, long-term upgrades to the system. A broad range of emergency management issues is discussed in the Emergency Operations Plan, which is being revised and expanded. The personnel, communications, and operational aspects of emergency management are dealt with in the Emergency Operations Plan. In the current context of distribution system upgrades, the most germane aspect of the emergency planning subject is the acquisition, location, and deployment of emergency generators and emergency pumps.

Emergency generators (fixed location or portable) replace grid power during times when the electric grid is temporarily down. Emergency pumps may replace normal pumps when the normal pumps are inoperable due to maintenance or damage. Emergency pumps may also augment the pumping capacity at a particular location when water demand is exceptionally high (for example, during a major wildland/urban intermix fire).

The District's need for emergency generators is likely to be determined primarily by post-earthquake performance objectives because major earthquakes are expected to produce the longest and most widespread power outages faced by the District. For the largest, most-critical pumping plants, fixed emergency generators may be warranted. For other large pumping plants, either fixed or portable generators should be available. These major pumping plants feed water not only to the larger pressure zones at the base of the cascades, but also supply all of the reservoirs higher in the cascades. For the smaller pressure zones, higher in the cascades, portable generators probably suffice to provide emergency power when needed.

Immediate or quick availability of emergency generators would somewhat augment fire flows available in major wildland/urban intermix fires. However, as discussed in Section 5.4 Fire Flow Durations, it is recommended that the District rely principally on storage, rather than pumping, to provide fire flow durations. Pumping can augment fire flow durations, but because of the cascaded system and the limited capacities of the pumping plants, it is difficult to rely on pumping to provide fire flows concurrently to several pressure zones in the same cascade.

When water demand is unusually high, or when normal pumps are unavailable due to maintenance or damage, emergency pumps can provide an important augmentation of water supplies available to a given pressure zone. The District should have an adequate supply of emergency pumps and all pumping plants should have quick connects for the pumps. Furthermore, all pumping plants should have pumper hydrants available. Portable water systems, operated by fire agencies, provide another means for emergency transfer of water from where it is available to where it is needed.

Since the October 1991 fire, the District has redeployed emergency equipment to ensure quicker access and installation in emergency situations and a fixed emergency generator has been installed at the Claremont Center. The District may require a few more emergency generators and emergency pumps for fire emergencies. Additional equipment is available via mutual aid from other agencies. Post-earthquake needs for emergency

generators are likely to be much greater than in fire emergencies; evaluation of the post-earthquake emergency equipment needs should be an important priority for the District's ongoing Seismic Evaluation Program.

One issue which merits consideration is the adequacy of the District's two fuel trucks to fuel emergency generators. In a fire situation, the two trucks (augmented by commercial fuel trucks if necessary) are probably adequate. However, in a major earthquake non-District fuel trucks may not be readily available and two trucks may not suffice. Standby sources should be procured and/or mutual aid agreements should include fuel trucks.

5.9 Impact of Fire Upgrades on Other Hazards Facing the District

The major hazards facing the District were reviewed in Chapter 3. In addition to fire, there were eight other hazards reviewed: earthquake, power outages, ground failure (landslides), dam failure, freeze, floods, contamination of water supplies, and drought. The analysis and recommendations discussed in preceding sections of this report have focused on enhancing the water distribution system's capability for fire emergencies. However, the distribution system upgrades which have been recommended for fire emergencies also, in some cases, augment the system's response capability for other types of hazards and disasters. The efficacy of the fire-based upgrade recommendations on the other hazards facing the District is briefly reviewed below.

Earthquakes

Major earthquakes are expected to have two major impacts on the District. First, there will be damage and disruption of the District's infrastructure. Second, post-earthquake water usage may be extremely high due to earthquake damage to District infrastructure and to customer services and due to the possibility of multiple post-earthquake fires. The recommended pipe replacements to improve fire flows will have some beneficial effect on seismic vulnerability because many of the upgrades involve replacing old, particularly vulnerable cast iron pipe, with newer more resistant welded steel pipe. The recommended increases in fire flow duration (more storage) will also improve the system's post-earthquake performance by replacing some vulnerable redwood reservoirs and by enlarging fire flows and durations available for post-earthquake multiple fire ignitions. The greater in-zone storage and the improved interconnections between zones will also enhance the District's inventory of water which is expected to be available and also enhance the District's ability to move the water where it is needed. Therefore, the fire-based enhancements do contribute significantly to post-earthquake performance. However, as discussed earlier, the seismic vulnerability of District facilities is an important issue which must be fully addressed in a complementary way to fire-based upgrades. The District's ongoing Seismic Evaluation Program should consider the installation of seismically-activated valves to close off flow out of a reservoir until the status of main lines can be determined. Under post-earthquake conditions, such valves would help to preserve water for fire fighting as well as for other essential needs.

Power Outages

The fire recommendations of greater storage and greater interconnections will benefit the District's response to power outages, by providing a greater margin of supply and an enhanced ability to redirect water around facilities affected by power outages. In addition, the greater emergency response capability (emergency planning as well as emergency equipment) recommended for fire preparedness will substantially improve the District's response capability for all types of power outages. The better deployment of emergency generators and pumps, augmented inventories of emergency equipment, and the installation of standby generators at selected facilities will improve the District's response to power outages. However, for planning purposes, earthquakes, which may cause prolonged power outages over wide portions of the service area, principally determine the extent to which emergency generators are necessary for District facilities.

Ground Failure (landslides)

Major landslides are nearly certain to destroy pipes in their slide zones. However, the greater storage proposed under the fire recommendations will give the District a greater margin of supply while landslide damage is repaired. Furthermore, the proposed increase in interzone connections will augment the District's ability to redirect water around landslide damage areas. The District should map all landslide areas within its service area and avoid installing new pipe in such areas unless stabilization of the landslide is practical and has been done. Pipes in existing landslide areas should be tabulated. When breaks occur or under normal maintenance and operations, such pipes should be rerouted if possible or the landslide areas stabilized.

Dam Failures

Possible dam failures affect the District's transmission system and the 23 open-cut reservoirs in the distribution system. Fire-based enhancements to the distribution system (particularly increased storage) somewhat reduce the importance of any single reservoir, but do not, obviously, improve dam safety. Dam safety is particularly significant in combination with the seismic risk faced by the District.

Freeze

An intense winter freeze could increase water demand from customers (including broken services). The greater storage proposed under the fire recommendations will give the District a greater margin of supply while freeze damage is repaired and the increase in interzone connections will augment the District's ability to redirect water to areas where demand is unusually high.

Floods

Overall, there is little overlap between fire-based upgrades and the distribution system's limited vulnerability to floods, mainly flood damage to localized facilities. To some degree, however, the recommended fire-upgrades will enhance the District's flood performance by ensuring more water is in storage before a flood and by enhancing the District's ability to move water where it is needed. Thus, the fire upgrades will help the District bypass flood damaged facilities or allow a greater margin of time to repair the damaged facilities.

Contamination of Water Supplies

The fire recommendations for greater storage and more interconnections give the District a marginally greater supply of potable water in case water supply is interrupted system-wide or locally due to water contamination, assuming that such contamination can be isolated from the remainder of the water distribution system. In addition, the enhanced interzone connections augment the District's ability to redirect water if a contamination event is local in impact.

Drought

Drought affects the District's transmission system rather than the distribution system. Therefore, enhancements to the distribution system (fire-based or other) have little impact in improving the District's response capability for droughts.

6.0 SUMMARY OF RECOMMENDATIONS: BOARD POLICY/ACTION ITEMS

Implementation of the recommendations contained in this report requires several Board policy decisions and actions, as well as actions by other agencies. To assist in this process, we outline briefly some of the key steps.

1. Mitigation of fire hazards before a fire disaster is the most effective hazard reduction action. The District should reaffirm its strong commitment to work with fire agencies, local governments and private groups to mitigate fire hazards in the high hazard areas.
2. The boundaries of the high hazard residential hill areas within the District's service area have not been defined, outside of the cities of Oakland and Berkeley. The District should work proactively with fire agencies to delineate the high hazard residential hill areas within the District's service area and to encourage the fire agencies to establish uniform fire flow standards for new construction in these high hazard areas. The fire flow requirements should explicitly address fire flow rates, fire flow durations, and multiple front fire suppression capability.
3. The Uniform Fire Code fire flow standards are designed for single structure fires. They were not designed for major wildland/urban intermix fires and thus do not provide adequate fire flows for such fires. Therefore, if the District, its customers, and the fire agencies within its service area desire a water system better designed to provide water for suppression of major wildland/urban intermix fires, then the standards for the water system must be set well beyond current UFC standards.
4. For new construction, in one- and two-family residential areas with high fire hazard potential, we suggest that the following guidelines would substantially improve the water distribution system's emergency response capability:
 - a) fire flows: 1,500 gpm from each hydrant
 - b) fire flow durations: 3,000 gpm for four hours in each pressure zone, and
 - c) multiple front capability: to support concurrent fire suppression at any two locations within each pressure zone.
5. The UFC fire flow requirements are for new construction. For the existing water distribution system, the District should establish District-wide objectives for the system's performance. In the high hazard residential hill areas, to address major wildland/urban intermix fires, the performance objectives or standards should deal with fire flows, fire flow durations, and multiple front fire suppression capability.
6. In the context of considering fire flow upgrades, we note that the current fire flow performance of the District's water distribution system is not well characterized. Detailed hydraulic analyses to determine fire flows have recently been completed for only 11

pressure zones. Field tests of fire flows appear to be done infrequently and/or the information does not appear to be readily available. To assist in long term planning, in prioritizing upgrades, and in prioritizing maintenance activities, we strongly suggest that the District begin to systematically compile data on the current fire flow performance of its entire water distribution system.

7. There are a wide range of possible distribution system upgrade alternatives to improve fire emergency performance. In the order of importance, recommended upgrade priorities are:

- 1) increase hydrant flow rates for hydrants which are substantially below current standards,
- 2) increase water storage in pumped pressure zones, especially zones with smaller reservoirs, and
- 3) enhance the distribution system's ability to support concurrent fire suppression efforts at multiple locations within a single pressure zone.

8. There are, two aspects of these possible upgrades where additional studies may be required or are necessary. First, the cost estimates are approximate because the boundaries of the high hazard residential hill areas have not yet been clearly delineated and engineering analyses beyond the 11 pressure zones studied to date have not been conducted. Therefore, additional analysis would improve the cost estimates. Second, detailed engineering analyses are clearly required before actual design and construction is undertaken. In particular, water quality and other operational aspects of the prospective upgrades must be carefully analyzed before any construction is undertaken. The ultimate objective of this assessment and planning process should be a coherent and coordinated system-wide repair/upgrade plan, for both the transmission and distribution system, which balances and prioritizes competing needs for resources, including: normal operations and maintenance, water quality, fire emergency performance, post-earthquake performance, environmental impacts.

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